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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

MANPOWER STAFFING, EMERGENCY DEPARTMENT ACCESS AND CONSEQUENCES ON PATIENT OUTCOMES

by

Alvin Tan Soon Meng

June 2007

Thesis Advisor:	Shen, Yu-Chu
Co-Advisor:	Hsia, Renee

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13. ABSTRACT (maximum 200 words)

Pressure on emergency medical services (EMS) is rising. The growth in EMS utilization has coincided with a decline in the number of emergency departments (ED). Between 1994 and 2004, the annual number of ED visits in the United States rose by 18 percent (from 93 million to 110 million) whereas the number of hospitals operating 24-hour EDs decreased by 12 percent during the same time frame. This study has three objectives: (1) analysis of diversion trends, (2) effect of ED staffing, capacity and financial characteristics on ED diversion hours and (3) effect of changes in ED access on mortality rates. For the first objective, we employ descriptive statistics to study ED diversion trends. For the second analysis, we use a two-part model to study the effect of hospital staffing, capacity and financial characteristics on diversion hours. For the third objective, we use simple ordinary least squares and fixed effects techniques to determine the effect of ED access on mortality rates. In particular, we examine two measures of ED access: diversion hours (a temporary change in ED access) and distance to closest ED (a permanent change in ED access).

We find statewide ED diversion impact of California in 2005 to be 11 percent. This means hospital EDs in California in 2005 were on diversion status 11 percent of the time. Reducing the number of nurses increases the number of hours an ED is on diversion status. Interestingly, increasing the number of intern or student doctors in a hospital increases the number of hours an ED is on diversion status. For heart-related and cancer-related deaths, we find a positive correlation between distance and mortality rates. However, for diversion hours, we find it counterintuitive that increasing diversion hours reduces mortality rates. Further study will need to be done to verify this finding.

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MANPOWER STAFFING, EMERGENCY DEPARTMENT ACCESS AND CONSEQUENCES ON PATIENT OUTCOMES

Alvin Tan Soon Meng
Major, Singapore Army
B.S., National University of Singapore, 2002

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
June 2007

Author: Alvin Tan Soon Meng

Approved by:

Shen, Yu-Chu
Thesis Advisor

Hsia, Renee
Co-Advisor

Robert Beck, Dean
Graduate School of Business and Public Policy

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ABSTRACT

Pressure on emergency medical services (EMS) is rising. The growth in EMS utilization has coincided with a decline in the number of emergency departments (ED). This study has three objectives: (1) analyze trends in ED diversion (hours that hospitals have to shut down their ED and divert ambulances to other hospitals), (2) analyze the effect of ED staffing, capacity and financial characteristics on ED diversion hours, and (3) analyze the effect of ED access on mortality rates. For the first objective, we employ descriptive statistics to study ED diversion trends. For the second analysis, we use a two-part multivariate model to study the effect of hospital characteristics on diversion hours. For the third objective, we use ordinary least squares and fixed effects models to determine the effect of ED access on mortality rates of various conditions. In particular, we examine two types of ED access: diversion hours (a temporary change in ED access) and distance to closest ED (a permanent change in ED access).

Hospitals in California that have to shut down their ED services temporarily (i.e., on divert status) have increased from 63 percent in 2002 to 75 percent in 2005. Throughout 2005, EDs had to divert patients in ambulances away about 11 percent of the time.

Several capacity and staffing characteristics influence the amount of time that ED is on divert. In particular, increasing the number of nurses and the number of staffed beds at ED can help curtail the hours an ED is on diversion status. Interestingly, increasing the number of intern or resident doctors in a hospital is associated with increasing hours of ED diversion.

Distance to the closest ED has either a positive (for heart-related, injury and suicide-related and cancer-related deaths) or insignificant (for liver related conditions) effect on mortality rates. However, for diversion hours, we find it counterintuitive that increasing diversion hours reduces mortality rates for heart related deaths. In all cases, the magnitude of the ED access effect is extremely small even in the case of statistically significant findings. Further study will need to be done to verify this result.

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I. INTRODUCTION

A. BACKGROUND

Emergency departments (ED) play a vital role in the United States' health care system. They provide the only universally guaranteed right to health care in the United States – the right to a screening examination and emergency care.[1] EDs are expected to provide care for any patient, at any time and under any reasonable circumstance.[2] It is therefore necessary that EDs have surge capacity[3] in order to deal with predictable (daily and seasonal variations) and unpredictable (mass casualty events) patterns in ED volume. Surge capacity involves more than a single hospital or ED[4]. For predictable daily and seasonal surge events, facilities can redistribute patients to alleviate crowding on their EDs. Ambulance diversion (AD) offers one such avenue of patient redistribution.

In recent years, growth in the utilization of emergency medical services[5] (EMS) has coincided with a decline in the number of emergency departments (ED). Between 1994 and 2004, the annual number of ED visits in the United States rose by 18 percent (from 93 million to 110 million) whereas the number of hospitals operating 24-hour EDs decreased by 12 percent during the same time frame.[6]

---

[1] R.E. Malone, Dohan D., "Emergency Department Closures: Policy Issues." *Journal of Emergency Nursing* 2000; 26:380-383.

[2] Julius Cuong Pham, Ronak Patel, Michael G. Millin, Thomas Dean Kirsch, Arjun Chanmugam, "The Effects of Ambulance Diversion: A Comprehensive Review." *Academic Emergency Medicine* Vol. 13(11); 2006: 1220-1227.

[3] Surge capacity is the ability to effectively care for patients despite volume, severity of illness or resource utilization that is above the usual daily ED practice.

[4] Julius Cuong Pham, Ronak Patel, Michael G. Millin, Thomas Dean Kirsch, Arjun Chanmugam, "The Effects of Ambulance Diversion: A Comprehensive Review." *Academic Emergency Medicine* Vol. 13(11); 2006: 1220-1227.

[5] EMS denotes pre-hospital emergency medical services, such as 911 and dispatch, emergency medical response, field triage and stabilization, and transport by ambulance or helicopter to a hospital and between facilities. (Board on Health Care Services, *Hospital-Based Emergency Care: At the Breaking Point*, Future of Emergency Care Series, The National Academies Press; Washington D.C. 2007: p. 31).

[6] Catharine W. Burt, Linda F. McCaig, "Staffing, Capacity and Ambulance Diversion in Emergency Departments: United States, 2003-2004." *Advance Data from Vital and Health Statistics; No.376.* Hyattsville, MD: National Center for Health Statistics; 2006: 1-23.

Emergency department overcrowding has become a serious nationwide problem in the United States[7], with one third of EDs reporting daily crowding[8]. Crowding occurs when extreme volumes of patients in ED treatment areas force the ED to operate beyond its capacity.[9] It can lead to prolonged waiting room times, increases the number of patients leaving without being seen by the physician, decreases patient satisfaction, and worsens patient pain and suffering.[10]

Despite the political debate on what is considered adequate capacity and staffing requirement for EDs and anecdotal evidence of the danger of overcrowding on patient care, there are little systemic empirical studies addressing these issues. This thesis aims to fill the gap in the literature and inform the policy debate.

B. OBJECTIVES

The objectives of this thesis are twofold: (1) to provide empirical evidence on how variations in ED manpower staffing, capacity and financial resources influence the number of hours a hospital is on "diversion" status (i.e., time during which hospitals are unable to accept new patients therefore having to divert ambulances to other area hospitals); and (2) to provide empirical evidence to demonstrate or disprove claims that reduced ED access (diversion hours and distance to nearest ED) has led to an increase in adverse patient outcomes (e.g. death). Specifically, the primary research questions addressed in this thesis are:

(1) What is the current trend in ED diversion hours (i.e., hours that a hospital cannot accept patients due to ED saturation or other reasons, necessitating a diversion of ambulances to other nearby hospitals)?

---

[7] Jin H. Han, et al., "The Effect of Emergency Department Expansion on Emergency Department Overcrowding." *Academic Emergency Medicine*, Vol. 14; 2007:pp. 338-343.

[8] Robert W. Derlet, John R. Richards, and Richard L. Kravitz, "Frequent overcrowding in U.S. emergency departments." *Academic Emergency Medicine*, Vol. 8; 2001:pp. 151-155.

[9] Robert M. Cowan and Stephen Trzeciak, "Clinical Review: Emergency Department Overcrowding and the Potential Impact on the Critically Ill", *Clinical Care*, Vol. 9; 2005: pp. 291-295.

[10] Jin H. Han, et al., "The Effect of Emergency Department Expansion on Emergency Department Overcrowding." *Academic Emergency Medicine*, Vol. 14; 2007:338-343.

(2) How do manpower staffing, ED capacity (e.g., number of beds) and financial factors affect ED diversion hours?

(3) What is the effect of ED diversion hours and distance to nearest ED on patient mortality rates?

C. ORGANIZATION OF THESIS

The remainder of the thesis will proceed as follows. Chapter II discusses the existing literature on emergency medicine pertaining to topics in this thesis. Chapter III presents the data and methodology of the research. Chapter IV provides descriptive statistics of the sample data. Chapter V presents results of the multivariate analysis and Chapter VI provides the conclusions and discussions of this study.

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II. LITERATURE REVIEW

This chapter starts by defining the role of emergency departments in the U.S. health care system. It proceeds to review existing literature relating to ED staffing (emergency physicians and nurses) as well as the effect of ED access (ED crowding and ambulance diversion) on patient outcomes. It concludes with a section highlighting the contribution to current discussion afforded by existing literature.

A. THE ROLE OF EMERGENCY DEPARTMENTS IN THE U.S. HEALTHCARE SYSTEM

EDs operate around the clock: 24 hours a day, seven days a week, including public holidays. Popularized by a popular television series, the ED is also commonly known as the emergency room[11] (ER), emergency ward (EW) or the accident and emergency (A&E) department.

The traditional mission of the ED is to care for patients afflicted with injuries or illnesses which require urgent attention. Over the years, however, this role has expanded to accommodate the growing needs of communities, providers and patients. EDs now frequently provide primary care[12] when other healthcare options such as medical clinics and family physicians are not available. EDs are also a critical component of the healthcare safety net, providing considerable volume of care to uninsured patients and Medicaid beneficiaries who often cannot access health services elsewhere.[13] Referred to as the "canary in the coal mine" of the healthcare system, EDs are oftentimes

[11] The term "emergency room" is a misnomer because the ED typically consists of multiple rooms or areas. To name a few, these are typically the triage area, the resuscitation area, the general medical area and the pediatric area.

[12] Primary care is a term used for a healthcare provider who acts as a first point of consultation for patients. It is a patient's first point of contact with the health care system, prior to referral elsewhere within the healthcare system except in emergencies. Generally, primary care physicians are located within the community, as opposed to a hospital. Primary care commonly comes in the form of local clinics and family doctors.

[13] Board on Health Care Services, *Hospital-Based Emergency Care: At the Breaking Point*, Future of Emergency Care Series, The National Academies Press; Washington D.C. 2007: p. 18.

symptomatic of problems within the healthcare delivery system.[14] If a problem should exist in the system, the place it presents itself is usually in the ED. Additionally, the ED is an important public health partner, responsible for alerting public health agencies to possible threats in the community and at times counseling patients on prevention and self-care.[15]

Emergency department visits have been on the rise. Statistics from the National Ambulatory Medical Care Survey in 2004 reveal that visits to EDs have risen 18 percent between 1994 and 2004, to 110 million visits per annum. Over the same period, the number of emergency departments has decreased by 12 percent[16], echoing concerns that many EDs are operating either at, or over capacity.[17] This has raised serious doubts about the adequacy of the healthcare system's surge capacity, its ability to absorb a large influx of patients in the event of a catastrophe.

In 1986, Congress passed a law referred to by practitioners as EMTALA (Federal Emergency Medical Treatment and Active Labor Act) to address concerns that EDs were refusing treatment to patients who could not afford to pay.[18] EMTALA assigned a right to treatment for patients, regardless of financial status, by attaching a duty for hospitals to perform an 'appropriate' medical screening examination and to determine if an emergency condition exists.[19] If an emergency condition should exist, the hospital must provide appropriate stabilization treatment or transfer (and hospitalization if it is deemed necessary).[20] While hospital EDs are required by federal law to provide emergency care

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[14] Wellness Institute, "The Evolving Role of Emergency", 2007.

[15] Board on Health Care Services, *Hospital-Based Emergency Care: At the Breaking Point*, Future of Emergency Care Series, The National Academies Press; Washington D.C. 2007: p. 19.

[16] See BACKGROUND.

[17] The Emergency Medicine & Critical Care Arena – In Brief, "An Authoritative Round-Up of Trends, Statistics and Clinical Research", *Emergency Medicine and Critical Care Review*, 2006: pp. 8-9.

[18] Kevin J. Bennett, Elizabeth Baxley, and Janice C. Probst, "The impact of Resident Physician Coverage on Emergency Department Visits in South Carolina", *Southern Medical Journal*, December 1, 2003.

[19] Recommendations to the EMTALA Tag. Comments to EMTALA Technical Advisory Group. *American College of Emergency Physicians.* November 21, 2005.

[20] Catharine W. Burt, Linda F. McCaig, "Staffing, Capacity and Ambulance Diversion in Emergency Departments: United States, 2003-2004." *Advance Data from Vital and Health Statistics; No.376.* Hyattsville, MD: National Center for Health Statistics; 2006: p. 2.

to all who require it without regard for a patient's ability to pay, no federal funding is allocated to offset the costs of this care.[21] This places the heavy financial burden of uncompensated care on the shoulders of hospitals that see large numbers of uninsured patients.[22] The American Hospital Association (AHA) has calculated that the cost of uncompensated care was $26.9 billion for all community hospitals in 2004.[23] Additionally, the federal statute creates a litigious risk (by way of private cause or civil action) for hospitals and its staff members alike, increasing the complexity of the existing clinical, legal and economic environment.[24]

B. ED STAFFING AND ITS EFFECT ON PATIENT CARE

Emergency care is delivered by professionals in a demanding and fast-paced environment where healthcare providers are often required to make life-and-death decisions based on minimal information.[25] The ED comprises managers, clinicians and support staff. Clinicians include physicians of multiple specialties and nurses. Emergency physicians and nurses are the focus of this study. The next two sections provide elaboration on their tasks, demographic and professional characteristics, and staffing trends.

1. Emergency Physicians

Emergency physicians evaluate the presenting problems of patients, make diagnoses and initiate treatment.[26] Beyond emergency care, emergency physicians frequently have to provide primary care to uninsured patients whose only access to care is

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[21] Board on Health Care Services, *Hospital-Based Emergency Care: At the Breaking Point*, Future of Emergency Care Series, The National Academies Press; Washington D.C. 2007: p. 21.

[22] Ibid., p. 22.

[23] Catharine W. Burt, Linda F. McCaig, "Staffing, Capacity and Ambulance Diversion in Emergency Departments: United States, 2003-2004." *Advance Data from Vital and Health Statistics; No.376.* Hyattsville, MD: National Center for Health Statistics; 2006: p. 2.

[24] Recommendations to the EMTALA Tag. Comments to EMTALA Technical Advisory Group. *American College of Emergency Physicians.* November 21, 2005.

[25] Board on Health Care Services, *Hospital-Based Emergency Care: At the Breaking Point*, Future of Emergency Care Series, The National Academies Press; Washington D.C. 2007: p. 209

[26] Ibid., p. 210.

through EDs. Scheduled clinical duties aside, emergency physicians also spend hours per week performing unscheduled clinical duties, on-call backup, administrative work, teaching; and research.[27]

In their 2002 study of the emergency workforce in 1999, Moorhead *et al.* found that emergency physicians were predominantly male (83 percent) and white (82 percent), with an average age of 43 years. About 9 out of 10 emergency physicians received an MD degree and attended medical school in the United States. Moorhead *et al.* estimate the number of emergency physicians working in EDs in 1999 to be approximately 31,800.

The supply of board-certified emergency physicians is insufficient to staff all ED physician positions and in the absence of a large scale expansion of training effort, will continue to be insufficient for several decades.[28] This is not to say, however, that non-board-certified physicians are an unimportant component of the ED workforce. Many go on to attain high levels of competency in emergency care through post-residency education, directed skills training, and on-the-job experience.

2. Nurses

There are approximately 90,000 nurses working in EDs.[29] According to the Department of Health and Human Services' (DHHS) National Center for Health Workforce Analysis, ED nurses are usually non-Hispanic white (89 percent) and predominantly female (86 percent). The median age for ED nurses is 40 compared with 43 for other nurses.[30] In 2004, 13,115 RNs were credentialed as certified emergency nurses (CENs). There are also other advanced degree options for nurses, including master's and doctoral degree programs with various areas of specialization and

[27] John C. Moorhead, et al., "A Study of the Workforce in Emergency Medicine:1999", *Annals of Emergency Medicine*, Vol. 40:1; Jul 2002: pp. 3-15.

[28] Board on Health Care Services, *Hospital-Based Emergency Care: At the Breaking Point*, Future of Emergency Care Series, The National Academies Press; Washington D.C. 2007: p. 211.

[29] Ibid.

[30] Ibid., p. 230.

practice.[31] While the predominant function of nurses in EDs has to do with direct patient care, ED nurses also perform supervisory and administrative roles.

There is a national nursing shortage. 90 percent of states in a study on health workforce shortages cited nursing shortages as a major concern.[32] The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) reports that 126,000 nursing positions are unfilled in hospitals, accounting for an overall vacancy rate of 13 percent for nursing positions.[33] Critically, nursing shortages are concentrated in specialty care units which require the knowledge and skill sets of highly trained nurses, such as the ED.[34] The ENA reveals that during one 6-month period from September 2000 through February 2001, 42 percent of vacant RN positions were filled within 4 weeks. 55 percent of EDs required up to 6 months, and 7 percent required more than 6 months to fill vacant RN positions.[35] An overall vacancy rate of 11.7 percent is reported for EDs.[36]

The supply of nurses has been experiencing a creep in its average age. The median age has increased by 3 years (from 37 to 40) between 1988 and 2000.[37] However, shortages of nurses will be eased by favorable enrollment numbers in RN programs in recent years[38]. The demand for nurses, however, is also growing. By 2020, demand for

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[31] Board on Health Care Services, *Hospital-Based Emergency Care: At the Breaking Point*, Future of Emergency Care Series, The National Academies Press; Washington D.C. 2007: p. 230.

[32] The Center for Health Workforce Studies. Responses to health worker shortages: results of 2002 survey of states; Nov 2002.

[33] Kathy S. Robinson, Mary M. Jagim and Carl. E. Ray, "Nursing Workforce Issues and Trends Affecting Emergency Departments", *Top Emerg Med*, Vol. 26, No.4, 2004: pp. 276-286.

[34] Peter I. Buerhaus, *et al*., "Why are shortages of hospital RNs concentrated in specialty care units?", *Nurs Econ*, Vol. 18, No.3, 2000: pp. 111-116.

[35] Kathy S. Robinson, Mary M. Jagim and Carl. E. Ray, "Nursing Workforce Issues and Trends Affecting Emergency Departments", *Top Emerg Med*, Vol. 26, No.4, 2004: pp. 277.

[36] American Organization of Nurse Executives, "Acute Care Hospital Survey of RN Vacancy Rates", Washington, D.C.: Jan 2002.

[37] Board on Health Care Services, *Hospital-Based Emergency Care: At the Breaking Point*, Future of Emergency Care Series, The National Academies Press; Washington D.C. 2007: p. 230.

[38] 2003 saw a 10 percent enrollment increase in basic RN programs compared to 2002 while 2005 saw an approximate 5 percent increase.

nurses is estimated to exceed supply by 400,000. This is exacerbated by the fact that two thirds of the existing nursing workforce will retire by 2025.[39]

3. Effect of Staffing on Patient Care

There are a number of studies documenting higher adverse patient outcomes in hospitals with lower nurse-to-patient ratios. In 1999, Pronovost *et al.* found lower mortality rates among intensive care unit patients in units with higher staffing ratios.[40] Also in 1999, a report by the Health Institute for Health and Socio-Economic Policy, after examining four years worth of hospital discharge data from California, concluded that inpatient outcomes were positively correlated with staffing ratios. In 2002, Aiken *et al.* found that hospitals with lower staffing ratios were associated with higher numbers of patients experiencing adverse outcomes such as death within thirty days of admission and failure to rescue.[41] In the same year, Needleman *et al.* found shorter lengths of stays and lower rates of urinary tract infections when care was provided by registered nurses instead of licensed practical nurses or nurse aids.[42]

Nursing organizations, labor unions and legislators have been pushing for mandated nurse ratios. In 1999, motivated by adverse patient outcomes believed to be the result of poor nurse-to-patient ratios, California became the first state of the nation to mandate numeric staffing ratios for acute care hospitals. Although Governor Gray Davis signed AB394 into law in October 1999,[43] AB394 only went into effect in January 2004 after hearings to determine the specifics of the law were completed. The nurse staffing

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[39] Kathy S. Robinson, Mary M. Jagim and Carl. E. Ray, "Nursing Workforce Issues and Trends Affecting Emergency Departments", *Top Emerg Med,* Vol. 26, No.4, 2004: p. 277.

[40] Peter J. Pronovost, Mollie W. Jenckes, Todd Dorman, Elizabeth Garrett, Michael J. Breslow, Brian A. Rosenfeld, Pamela A. Lipsett, Eric Bass, "Organization Characteristics of Intensive Care Units Related to Outcomes of Abdominal Aortic Surgery." *The Journal of American Medical Association,* Vol 281(14); 1999: pp. 1310-1317.

[41] Linda H. Aiken, Sean P. Clarke, Douglas M. Sloane, Julie Sochalske, Jeffrey H. Silber, "Hospital Nurse Staffing and Patient Mortality, Nurse Burnout, and Job Dissatisfaction." *The Journal of American Medical Association,* Vol. 288(16); 2002: pp. 1987-1993.

[42] Jack Needleman, et al., "Nurse-Staffing Levels and the Quality of Care in Hospitals." *New England Journal Medicine,* Vol. 346(22); 2002: pp. 1715-1722.

[43] Kathy S. Robinson, Mary M. Jagim and Carl. E. Ray, "Nursing Workforce Issues and Trends Affecting Emergency Departments", *Top Emerg Med,* Vol. 26, No.4, 2004: p. 278.

ratios used by the California Department of Health are 1:4 general ED patients, 1:2 critical care ED patients and 1:1 ED trauma patient.[44] Reactions of ED nurses to the Californian staffing ratios are mixed. Some feel relieved over the improved staffing while others believe the law is too strict and is inflexible with respect to patient severity of illness.[45] Researchers like Hackenschmidt[46] duly note the lack of scientific rigor needed to support staffing ratio numbers.

Workforce shortages constitute one of the main causes of inadequate ED capacity.[47] McCaig *et al*. studied hospitals in the 2003-2004 National Hospital Ambulatory Care Survey (NHAMCS) and found staffing shortages to be responsible for 12 percent of ambulance diversion hours.[48] The current nursing shortage exacerbates the lack of inpatient capacity by further decreasing the number of staffed beds available to offload an overcrowded ED.[49] Without the adequate amount of nurses, EDs are unable to transfer patients to inpatient beds once the decision to admit them has been made.

C. EMERGENCY DEPARTMENT CROWDING AND AMBULANCE DIVERSION AND THEIR CONSEQUENCES ON PATIENT OUTCOMES

Factors like demand exceeding capacity, increasing scope of ED responsibilities, excess and non-urgent use of EDs have all conspired against the smooth functioning of EDs. Increasingly, EDs are frequently very crowded environments and patients often

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[44] Board on Health Care Services, *Hospital-Based Emergency Care: At the Breaking Point*, Future of Emergency Care Series, The National Academies Press; Washington D.C. 2007: p. 233.

[45] Ibid.

[46] Angela Hackenschmidt, "Living with nurse staffing ratios: Early experiences", *Journal of Emergency Nursing*, Vol. 30(4); 2004:377–379.

[47] Robert W. Schafermeyer and Brent R. Asplin, "Hospital and Emergency Department Crowding in the United States", *Emergency Medicine*, Vol. 15; 2003: pp. 22-27.

[48] Catharine W. Burt, Linda F. McCaig, "Staffing, Capacity and Ambulance Diversion in Emergency Departments: United States, 2003-2004." *Advance Data from Vital and Health Statistics; No.376.* Hyattsville, MD: National Center for Health Statistics; 2006: p. 6.

[49] Robert M. Cowan and Stephen Trzeciak, "Clinical Review: Emergency Department Overcrowding and the Potential Impact on the Critically Ill", *Clinical Care*, Vol. 9; 2005: pp. 291-295.

have to be "boarded". This means holding patients in the ED, usually in beds or hallways, until inpatient beds become available. In busy EDs, waiting times can exceed 48 hours.[50]

There has been mounting evidence that ED overcrowding may negatively affect the quality of care. In 2003, Schull *et al.* found that an increase in overcrowding in EDs was associated with a substantial increase in ambulance transport times for patients with chest pain.[51] In a 2004 study of 25 community and teaching hospital EDs between 1998 and 2000, Schull *et al.* found ED crowding to be associated with increased door-to-needle times for patients with suspected acute myocardial infarction and may represent a barrier to improving cardiac care in EDs.[52] In 2006, Richardson concluded from his cohort-analysis study that cohorts of patients presenting when the ED was overcrowded had a significantly higher 10-day in-hospital mortality than a similar cohort treated when the ED was not overcrowded.[53]

Particularly relevant to this thesis is that overcrowded EDs result in a serious problem called ambulance diversion. Ambulance diversion is the practice of rerouting ambulances away from the closest ED because of a variety of reasons such as ED crowding, patient's personal preferences, or the hospital's lack of adequate facilities or trained personnel. At times, individuals may request to be treated in a specific medical facility for personal reasons (e.g., insurance, family physician etc.). In other instances, institutions may lack necessary specialized equipment or trained personnel required for patient-specific medical conditions. However, the most common reason for ambulance diversion is the alleviation of ED overcrowding. Mostly, facilities which have exceeded their capacity divert ambulances out of concern for the safety of those patients currently in ED and those being diverted away.

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[50] Robert B. Giffin, et al., "The Future of Emergency Care in the United States Health System", Report Brief, 2006., *Institute of Medicine of the National Academies*, June 2006.

[51] Michael J. Schull, Laurie J. Morrison, Marian Vermeulen and Donald A. Redelmeier, "Emergency Department Overcrowding and Ambulance Transport Delays for Patients with Chest Pain", *CMAJ*, Vol. 168(3); 2003: pp. 277-283.

[52] Michael J. Schull, Marian Vermeulen, Graham Slaughter, Laurie J. Morrison, Paul Daly, "Emergency Department Crowding and Thrombolysis Delays in Acute Myocardial Infarction", *Annals of Emergency Medicine*, Vol. 44; 2004: pp. 577-585.

[53] Drew B. Richardson, "Increase in Patient Mortality at 10 Days associated with Emergency Department Overcrowding", *Med J Aust*, Vol. 184; 2006: pp. 213-216.

The problems of ED overcrowding and ambulance diversion have reached a dangerous point[54], and deriving effectual solutions to alleviate these problems have become more pressing than ever. In their report to the U.S. Senate, the General Accounting Office (GAO) found that 2 out of every 3 hospitals diverted ambulances to other hospitals at some point in fiscal year 2001.[55] In 2006, Sun *et al.* concluded from their study that hospital closure was associated with a significant but transient increase in ambulance diversion for the nearest ED.[56] Based on their study of ambulance diversions in the United States between 2003 and 2004, McCaig and Burt were able to find specific causes of ambulance diversion. The six main reasons were lack of inpatient beds, high volume of ED patients (ED crowding), complexity of ED cases, hospital staffing shortage and equipment failure. Of the six, lack of inpatient beds and ED crowding were reasons cited most frequently.

Ambulance diversion durations vary widely but are frequently reported to be within the range of 3 to 4 hours[57] and reportedly have negative impact on patient safety. Ambulance diversions potentially delay patient arrival to the ED and may also reduce ambulance availability for other patients.[58] Schull *et al.* reported that when ambulance diversions resulted in gridlock, ambulance diversions were associated with delays in ambulance transport for cardiac patients.[59]

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[54] Jin H. Han, et al., "The Effect of Emergency Department Expansion on Emergency Department Overcrowding." Academic Emergency Medicine, Vol. 14; 2007:338-343.

[55] General Accounting Office. "Hospital Emergency Departments: Crowded Conditions Vary Among Hospitals and Communities. Washington D.C., General Accounting Office, 2003.

[56] Benjamin C. Sun, Sarita A. Mohanty, Robert Weiss, Richard Tadeo, Maureen Hasbrouck, William Koenig, Carol Meyer, Steven Asch, "Effects of Hospital Closures and Hospital Characteristics on Emergency Department Ambulance Diversion, Los Angeles County, 1998-2004", *Annals of Emergency Medicine*, Vol. 47(4); 2006: pp. 309-316.

[57] Catharine W. Burt, Linda F. McCaig, "Staffing, Capacity and Ambulance Diversion in Emergency Departments: United States, 2003-2004." *Advance Data from Vital and Health Statistics; No.376.* Hyattsville, MD: National Center for Health Statistics; 2006: p. 6.

[58] Julius Cuong Pham, Ronak Patel, Michael G. Millin, Thomas Dean Kirsch, Arjun Chanmugam, "The Effects of Ambulance Diversion: A Comprehensive Review." *Academic Emergency Medicine*, Vol. 13(11); 2006: p. 1221.

[59] Michael J. Schull, Lauries J. Morrison, Marian Vermeulen, Donald A. Redelmeier, "Emergency Department Gridlock and Out-Of-Hospital Delays for Cardiac Patients", *Academic Emergency Medicine*, Vol. 10; 2003: pp. 709-716.

While patient transport and treatment times may be lengthened by ambulance diversion, the impact of such delays is mostly unknown. Pham *et al.* conclude from their comprehensive review (on the effects of ambulance diversion) that ambulance diversion does not appear to be associated with mortality although it may "affect morbidity end points such as patient and provider satisfaction, intubation rates for asthma patients and so on."[60]

D. CONTRIBUTION TO THE CURRENT LITERATURE

Much of the existing literature on ED crowding are performed at patient level. Oftentimes, this results in researchers focusing on case studies or relying on observations from only one or two ED settings. As a consequence, research outcomes may not be applicable to other EDs which do not espouse similar characteristics. This thesis provides a systemic analysis of ED crowding by studying all hospital EDs in California between 2002 and 2005.

We identify ED access as having two main components: (1) number of hours a hospital is on diversion status and (2) the distance to the nearest ED. These two components represent a temporary and permanent change in ED access respectively and provide a fresh perspective in understanding effects of ED access on patient outcomes.

[60] Julius Cuong Pham, Ronak Patel, Michael G. Millin, Thomas Dean Kirsch, Arjun Chanmugam, "The Effects of Ambulance Diversion: A Comprehensive Review." *Academic Emergency Medicine*, Vol. 13(11); 2006: p. 1225.

III. METHODOLOGY

This chapter identifies sources and provides tabulations of the data. It then goes on to set up statistical models for the two multivariate analyses: (1) a hospital level analysis exploring the effect of ED staffing and capacity on ED access (henceforth known as manpower analysis) and (2) a zip code level analysis of ED access on mortality (henceforth known as patient outcome analysis). This chapter concludes with a section highlighting limitations of the study.

A. DATA SOURCES

The manpower analysis utilizes the following data sources: daily hospital diversion data from EMS agencies, California Office of Statewide Health Planning and Development hospital facility report, and the American Hospital Association annual survey.

In addition to the data sources used in the manpower analysis, the patient outcome analysis also utilizes data from the following sources: California mortality rate data at zip code level, zip code distance data to the closest ED, and Census data on population characteristics at the zip code level.

1. Daily Hospital Diversion Data from EMS Agencies

There are a total of 31 EMS regions in California. For daily diversion hours, we obtain data for four EMS regions (Santa Clara, San Mateo, San Francisco and Los Angeles) from their respective EMS agencies. The table below summarizes time periods and duration data for the four EMS regions.

Diversion Data Sources

Location	Time Period (Start)	Time Period (End)	Duration (No. of Months)	Obs	No. of Hospitals	Source	Description
Santa Clara (SC)	Jan-03	Dec-06	48	15,916	13	EMS Region - Santa Clara	Daily Diversion Hours
San Mateo (SM)	Oct-99	Nov-06	85*	7,207	10	EMS Region - San Mateo	Daily Diversion Hours
San Francisco (SF)	Jan-94	Dec-98	60	624	11	EMS Region - San Francisco	Monthly Diversion Hours
San Francisco (SF)	Oct-99	Dec-02	39	45,484	13	EMS Region - San Francisco	Daily Diversion Hours
Los Angeles (LA)	Jun-01	Dec-04	43	103,900	80	EMS Region - Los Angeles	Daily Diversion Hours
California (Statewide)	2002	2005	NA	2,262	496	California Office of Statewide Health Planning and Development Hospital Facility Report	Annual Diversion Hours

(*There were no observations for Nov-99)

Table 1. Diversion Data Duration and Source for selected EMS Regions.

For San Francisco County, we obtain additional data containing monthly diversion hours for the period between January 1994 and December 1998. This is used to augment the trend analysis of diversion hours for San Francisco.

Between San Mateo and San Francisco counties, there are 5 hospitals which overlap because they are reported by both EMS regions for the years between 1999 and 2002. For individual county trend analysis, we leave the five hospitals in the dataset. However, when performing statewide studies on California, we omit the five hospitals from San Mateo County to prevent double-counting.

2. Office of Statewide Health Planning and Development Facility Report

We supplement daily diversion hours with monthly and annual diversion hours for all hospitals in California from the California Office of Statewide Health Planning and Development (OSHPD) hospital facility report. Annual diversion data span from 2002 to 2005 (4 years). The OSHPD report also contains a unique identifier for every hospital in California. Where the years overlap, we aggregate daily diversion data for the four EMS regions (Santa Clara, San Mateo, San Francisco and Los Angeles) into annual diversion hours and replace corresponding entries within the OSHPD dataset. This extra

step is performed to obtain better accuracy because the OSHPD questionnaire does not break down the types of diversion, potentially overstating diversion hours since certain diversion categories cannot be specifically removed.[61]

In addition to the diversion hours for all hospitals in California, we also use OSHPD facility reports to obtain information on physical capacity of hospitals, such as number of ED stations (i.e., beds).

We exclude the following types of hospitals from our analysis: non-acute general hospitals, children's hospitals, rehabilitation centers, psychiatric institutes, hospices, and any other specialty hospitals. In addition, we further exclude hospitals without an ED license for the full year and hospitals from EMS regions with legislation prohibiting patient diversion are also removed.[62] The analytical OSHPD dataset for the thesis contains an unbalanced panel of 282 hospitals in 2002, 268 hospitals in 2003, 273 hospitals in 2004 and 263 hospitals in 2005, for a total of 1086 observations.[63]

3. American Hospital Association (AHA) Annual Survey

The AHA dataset contains staffing information on different types of nurses and resident / intern doctors, which is not available in the OSHPD dataset. While it also contains a unique identifier for every hospital, unique identifiers in the AHA dataset are different from the ones used in the OSHPD dataset. Data in the AHA dataset spans between 2002 and 2005 (4 years). The AHA dataset contains 1166 observations.

A crosswalk containing both sets of unique identifiers is used as an interface to merge the OSHPD and AHA datasets. The merged dataset contains 997 observations.

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[61] The Abaris Group. California Emergency Department Diversion Project (Report One). A Report to the California Healthcare Foundation. March 19, 2007.

[62] These EMS regions are Contra Costa, El Dorado, Merced, Monterey, San Benito and Solano.

[63] Original dataset contains 2262 observations. After making 1176 exclusions, 1086 observations remain.

4. California Mortality Rate Data at the Zip Code Level

To determine the effect of ED access (distance to nearest hospital and diversion duration) on patient mortality outcomes, we use death reports published by the Office of Health Information and Research (OHIR) from California's Department of Health Services (CDHS). Mortality data (counts of death) is divided into zip codes where the zip codes are based on decedent's residence at time of death. Population data is obtained from Census 2000 and merged with the OHIR dataset. This will allow us to calculate mortality rates at zip code level.

We use cause-specific mortality data from 2001 to 2004 to test for an effect of distance to nearest hospital on mortality, contingent on conditions for which timely access to emergency care is crucial for survival. Specifically, we examine the effect of distance on mortality outcomes resulting from heart attacks, unintentional injuries and suicide. We also include deaths caused by pneumonia and influenza as these could result in respiratory difficulties which require immediate medical attention. We compare these results to the effect of distance on deaths caused by chronic diseases and cancer, ailments which should not be time-sensitive.

5. Zip Code Level Data on Distance to the Closest ED

Longitude and latitude information for each hospital was generously provided by Dr. Jill Horwitz (University of Michigan and the National Bureau of Economic Research). Distances between each residential zip code from mortality data and hospitals are computed using the standard calculation of spherical distance between the two locations' longitude and latitude.

B. STATISTICAL MODEL FOR HOSPITAL LEVEL ANALYSIS OF ED STAFFING AND CAPACITY (MANPOWER ANALYSIS)

The manpower analysis is performed at hospital level for the years 2002 through 2005 and aims to determine the effect of ED staffing, physical capacity and hospital financial characteristics on patient access.

Between 25 to 35 percent of hospitals reported no diversion hours in each year. Due to the high percentage of zeroes in dependent variable observations, we use a two-part model[64]. The two-part model is commonly used to estimate health expenditure models but is equally appropriate in this context because the empirical distribution of diversion hours is very similar to that of health expenditure. The first part of the model involves a probit estimation where the dependent variable is a binary indicator for whether or not a hospital was ever on "diversion" status for the given year. The second part is a fixed effects ordinary least squares (OLS) regression restricted to those hospitals which had non-zero diversion hours in each year, where the dependent variable is a continuous variable of total annual diversion hours on the log scale.

The general form of the first part of the econometric specification is:

$$\text{Prob}(Y = 1) = \alpha_t + X\beta + u_{it}$$

where

Y = a binary variable (1 = experienced non-zero diversion hours)

α_t = year dummies

u_{it} = error term

X = a set of ED staffing, hospital capacity and financial factors

The general form of the second part of the econometric specification is:

$$\log(div_hrs \mid Y > 0) = \alpha_t + X\beta + \gamma_i + u_{it}$$

where

div_hrs = total annual diversion hours

α_t = year dummies

[64] Naihua Duan; Willard G. Manning, Jr.; Carl N. Morris; Joseph P. Newhouse, "A Comparison of Alternative Models for the Demand for Medical Care", *Journal of Business and Economic Statistics*, Vol. 1 No. 2; Apr 1983: 115-126

γ_i = hospital fixed effects

u_{it} = error term

X = a set of ED staffing, hospital capacity and financial factors

Based on prior literature, we include the following independent variables for both models:

- Manpower staffing: *intern doctor-to-bed ratio, nurse-to-bed ratio*
- Size of ED: *number of beds set up in ED*
- Financial resources: *total net patient revenue, percentage net patient revenue from Medicaid, percentage net patient revenue from Medicare, percentage net patient revenue from third party payers*
- Demand factors: *volume of urgent and non-urgent patient visits, volume of visits to the ED*

C. STATISTICAL MODEL FOR ZIP CODE LEVEL ANALYSIS OF ED ACCESS AND PATIENT MORTALITY (PATIENT OUTCOME ANALYSIS)

To fully utilize the data, apart from conducting patient outcome analyses which include both measures of ED access (distance to nearest hospital ED and level of diversion), patient outcome analysis is also conducted separately for distance to nearest ED only.

For distance to nearest hospital ED, we perform a zip code level analysis incorporating mortality data for the years 1990 through 2004 (the latest available year on mortality). For the regression which includes both distance and diversion level, patient outcome analysis is conducted at zip code level for the years 2002 through 2004. In both cases, we perform a fixed effects regression where the dependent variable is a continuous variable describing patient mortality rates by cause.

The general form of the econometric specification is:

$$Y_{jt} = \alpha_t + \beta_1 dist_{jt} + \beta_2 divert + \beta_3 X + \beta_4 Z_j + \varepsilon_{jt}$$

where

Y	=	annual mortality rate for zip code *j* in year *t*
α_t	=	year dummies
$\beta_1 dist_{jt}$	=	actual distance between decedent and nearest hospital *j* in year *t*
$\beta_2 divert_{jt}$	=	categorical variable indicating yearly diversion level of the nearest ED *j* in year *t*.
X	=	a set of control variables
Z_j	=	zip code fixed effects

We include the following independent variables for both models (one model for each measure of ED access):

- Key Independent Variables: *distance to nearest hospital ED, diversion level of nearest ED*
- Demographics: *gender (male), age>65 (elderly), race (black)*
- Income: *per capita income*
- Controls: *total deaths, deaths by homicide, zip code fixed effects and year dummies (total deaths captures the zip code mortality rate while homicide rate captures the crime rate of the area)*

Dependent variables included in the model describe mortality rates by cause:

- *Heart-related death rate*
- *Unintentional injury and suicide death rate*
- *Cancer death rate*
- *Chronic liver disease death rate*

D. LIMITATIONS OF STUDY

A possible limitation in the manpower analysis stems from using number of resident doctors and interns, and number of registered nurses as proxies for emergency physicians and nurses. While data of such specificity has been obtained in prior case studies (involving one or several hospitals), the OSHPD reports and AHA surveys do not

collect data at this resolution. However, we postulate that the size of a hospital's ED staff is highly correlated to the size of the hospital's workforce; therefore it is reasonable to use resident doctors and registered nurses as proxies for emergency department physicians and nurses. In addition, staffing information is only available on the annual basis, whereas diversion duration is a more time sensitive issue. Aggregated staffing information collected annually might not be sensitive enough to capture the effect staffing would have on diversion hours.

Another possible limitation comes from the patient outcome analysis. Zip code usage assumes the effect of distance to be the same for all residing in the area, which clearly may not be the case. Patient preferences, health insurance policy coverage restrictions and ED medical equipment limitations may necessitate some patients having to travel distances beyond the nearest hospital ED to receive necessary care.

IV. DESCRIPTIVE STATISTICS

This chapter presents summary statistics useful for providing context to the interpretation of manpower and patient outcome analyses. Section A provides readers with hospital diversion trends in four EMS regions and in the State of California. Section B presents summary statistics for the manpower analysis while Section C presents the same for the patient outcome analysis. Section D weights the populations affected by changes in measures of ED access: diversion hours and distance to the nearest hospital ED.

A. TREND ANALYSIS OF MEAN MONTHLY ED DIVERSION HOURS PER HOSPITAL

1. Analysis of Individual EMS Regions

We aggregate daily diversion hours into mean monthly diversion hours for four EMS regions: Santa Clara, San Mateo, San Francisco and Los Angeles. We obtain a hospital diversion trend line for each EMS region by plotting mean monthly diversion hours against time. We discuss the trend for each EMS region in this section.

Santa Clara. We study 13 hospitals from Santa Clara County between January 2003 and December 2006. For this period, mean monthly ED diversion in Santa Clara County never exceeded 40 hours. The maximum diversion duration of 39 hours occurs in February 2005 while the minimum of 9 hours occurs in August 2003. Figure 1 shows an increase in diversion duration from a mean of 14 hours in 2003 (95% confidence interval [CI] 11 to 17 hours) to a mean of 26 hours (95% CI 23 to 29 hours) in 2004 and then declining to a mean of 21 hours (95% CI 17 to 25 hours) in 2006. For Santa Clara County, we observe a seasonal trend with peaks usually occurring during December to February. Figure 1 below displays mean monthly diversion hours per hospital for Santa Clara County.

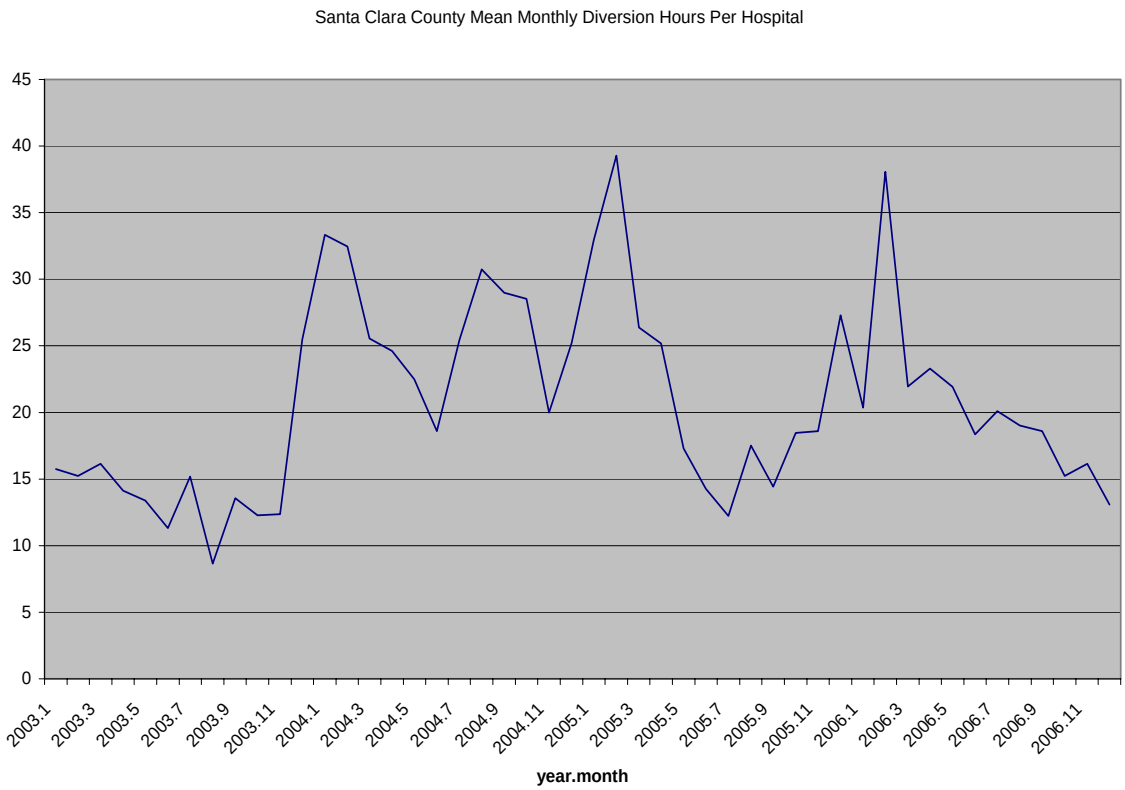

Figure 1. Mean Monthly Diversion Hours Per Hospital for Santa Clara County (2003-2006)

Santa Mateo. We study diversion data for 10 San Mateo County hospitals from October 1999 to November 2006. Figure 2 shows an increase in diversion duration from a mean of 18 hours in 1999 to a mean of 60 hours (95% CI 49 to 71 hours) in 2001 and then declining to a mean of 27 hours (95% CI 23 to 31 hours) in 2006. From the data, ED diversion hours in 2001 were more than twice the diversion hours in 2006. There is a clear downward trend in diversion hours. San Mateo does not display any obvious seasonal trends. Figure 2 below displays mean monthly diversion hours per hospital for Santa Clara County.

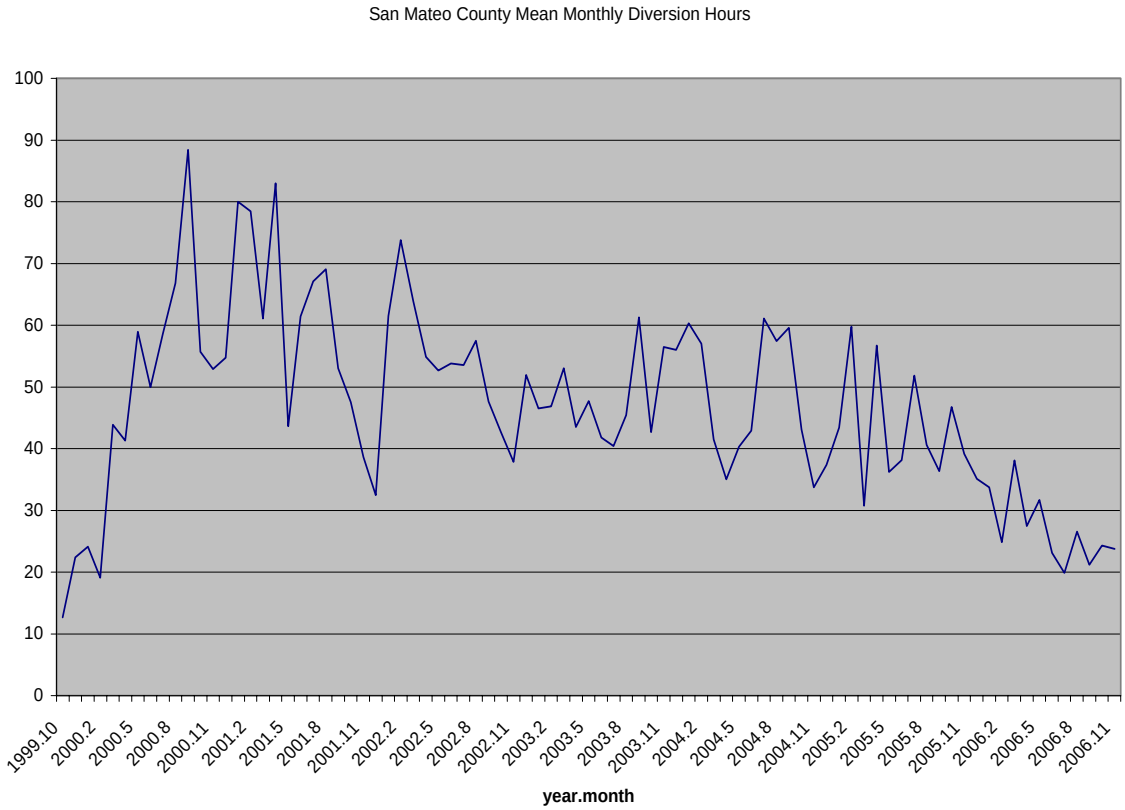

Figure 2. Mean Monthly Diversion Hours Per Hospital for San Mateo County (1999-2006)

San Francisco. The graph for San Francisco County (Figure 3) is constructed by combining a dataset containing mean monthly diversion data for 11 hospitals from January 1994 to December 1998, together with a separate dataset containing mean monthly diversion data for 13 hospitals from October 1999 to December 2002. The trend in Figure 3 shows a gap between January and September 1999 because there is no data available for that period. There is a significant spike in ED diversion hours from a mean of 17 hours (95% CI 14 to 20 hours) for the period 1994 to 1998, to a mean of 86 hours (95% CI 78 to 94 hours) between 2000 and 2002. We find ED diversion hours past the year 2000 to be at least four times higher than the same from 1994 to 1998. However, due to a lack of data, we are unable to tell if the increased levels of ED diversion persist beyond 2002. Figure 3 below displays mean monthly diversion hours per hospital for San Francisco County.

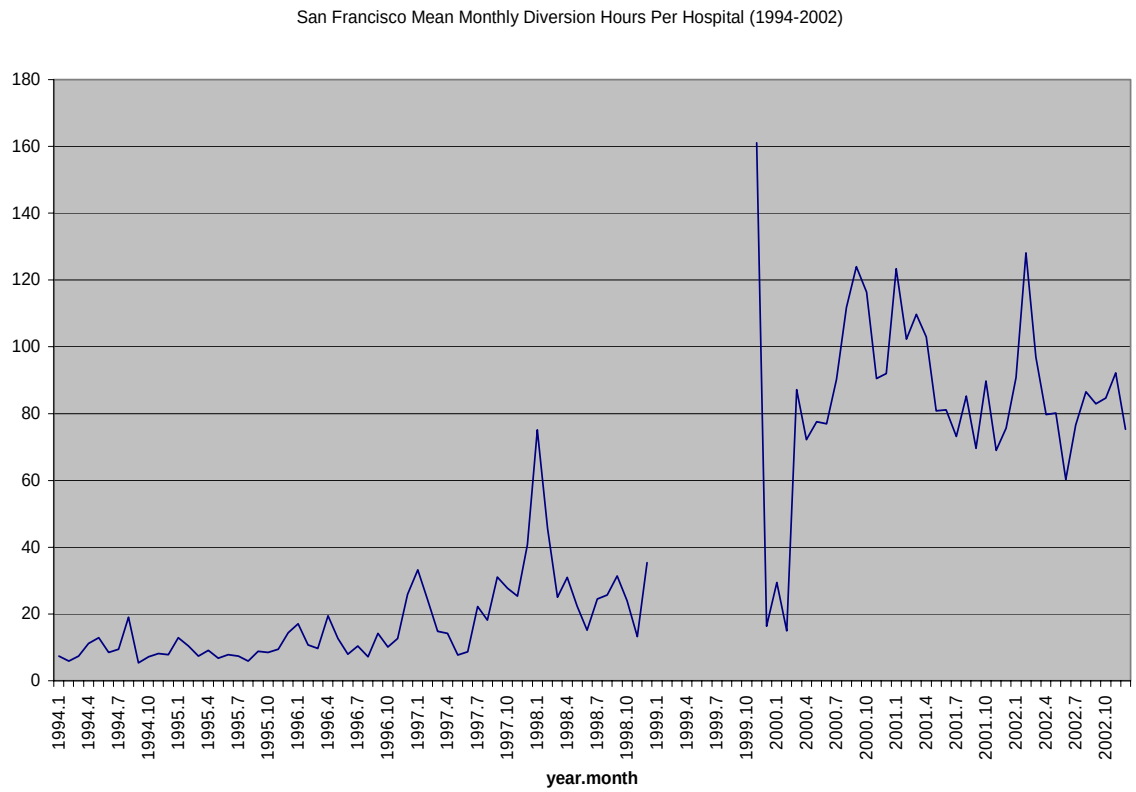

Figure 3. Mean Monthly Diversion Hours Per Hospital for San Francisco County (1994-2002)

Los Angeles. We study diversion data for 80 Los Angeles County hospitals from June 2001 to December 2004. Los Angeles County EMS Agency provides reasons for ambulance diversion. Of these reasons, we are primarily interested in ED saturation because they represent a proxy for crowding. Other reasons such as internal disaster or diversion for trauma care are conceptually different from diversion for ED saturation and are excluded from the analysis. We observe a mild increase in number of diversion hours over time from a mean of 182 hours (95% CI 156 to 208 hours) in 2001 to 195 hours (95% CI 168 to 222 hours) in 2004. 3 seasonal peaks occur consistently during December to February and they appear to alternate in magnitude by year. For the period of study, the maximum and minimum mean monthly diversion hours per hospital occur in December 2003 and November 2001 respectively. Figure 4 below displays mean monthly diversion hours per hospital for Los Angeles County.

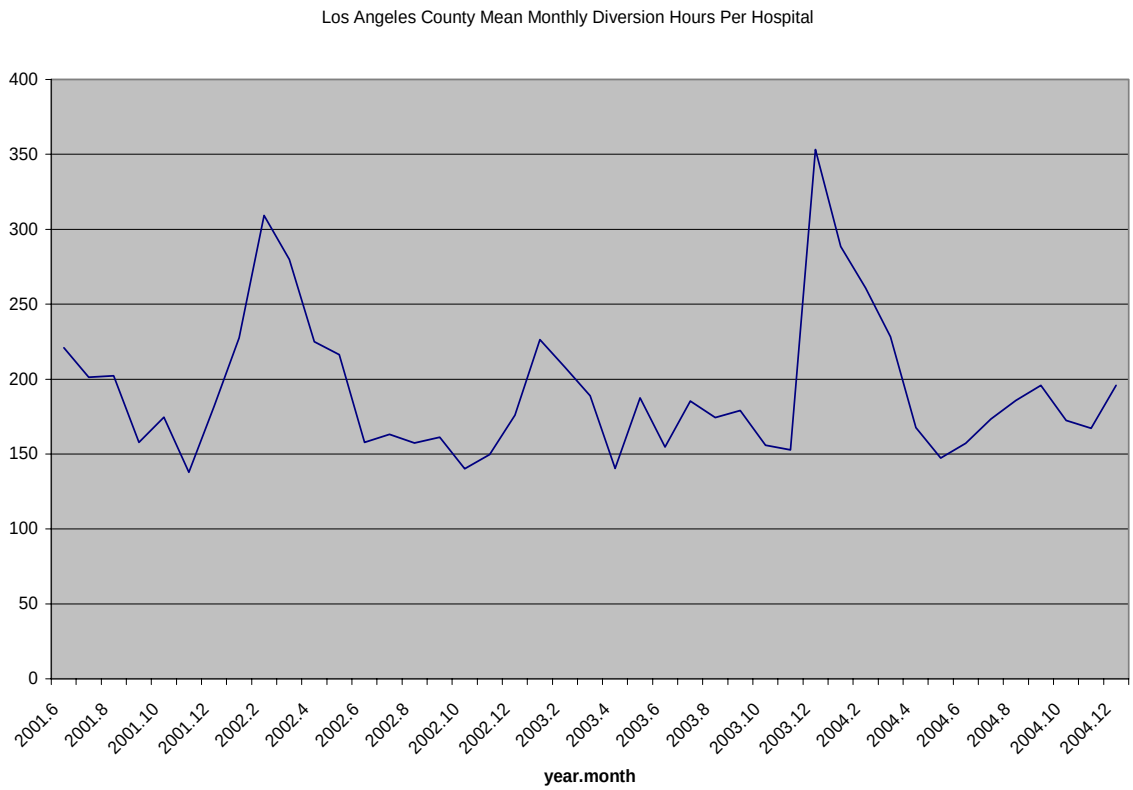

Figure 4. Mean Monthly Diversion Hours Per Hospital for Los Angeles County (2001-2004)

In addition to daily diversion hours, Los Angeles' EMS agency also captures the reasons for ED saturation. There is no obvious trend for any single reason for ED saturation. However, two main reasons for ED saturation stand out: multiple critical patients (high patient volume with high patient acuity) and unavailable inpatient beds (insufficient physical capacity). Together, they constitute 47 percent of all ED saturation occurrences. Table 2 below summarizes ED saturation categories for the Los Angeles County from 2001 through 2004.

Reason for ED Saturation	Year				Total Obs	%
	2001	2002	2003	2004		
Generalized Rash with Fever	7	7	8	14	36	0.04
Acute Febrile Respiratory Illness	18	23	49	17	107	0.11
Neurological findings (excl strokes)	22	34	38	66	160	0.16
Vomiting/Diarrhea/Gastroenteritis	47	87	92	70	296	0.29
Other Clinical Chief Complaint Not Listed	4,677	1,293	660	485	7,115	7.04
Multiple Critical Patients	-	6,502	6,945	6,266	19,713	19.50
Inpatient Beds Unavailable	3,590	7,513	8,422	8,189	27,714	27.42
No Single Chief Complaint Predominates	6,172	12,316	13,777	13,670	45,935	45.45
Total Obs	14,533	27,775	29,991	28,777	101,076	100
%	14.38	27.48	29.67	28.47	100	

Table 2. ED Saturation Categories for Los Angeles County (2001-2004)

2. Trend Analysis of All California Hospitals between 2002 and 2005

We study diversion hours of all California hospitals (where counties allow diversion) between January 2002 and December 2005. During this period, the number of hospitals in California decreased from 282 to 263. Mean diversion hours remain relatively constant, increasing only slightly from 77 hours (95% CI 62 to 92 hours) in 2002 to 80 hours (95% CI 73 to 87 hours) in 2005. Seasonal peaks occur consistently during December to February and they appear to alternate in magnitude by year.

We find that AB394, which became effective in January 2004 (Californian legislation mandating nurse-to-patient ratios of 1:4 for acute general hospitals), coincide with a temporary surge in diversion hours between December 2003 and February 2004 (the surge is higher than the usual seasonal peaks compared to other years). The peak diversion duration of 143 hours for California occurs in December 2003 and declines sharply till May 2004. Figure 5 below displays mean monthly diversion hours per hospital for the State of California.

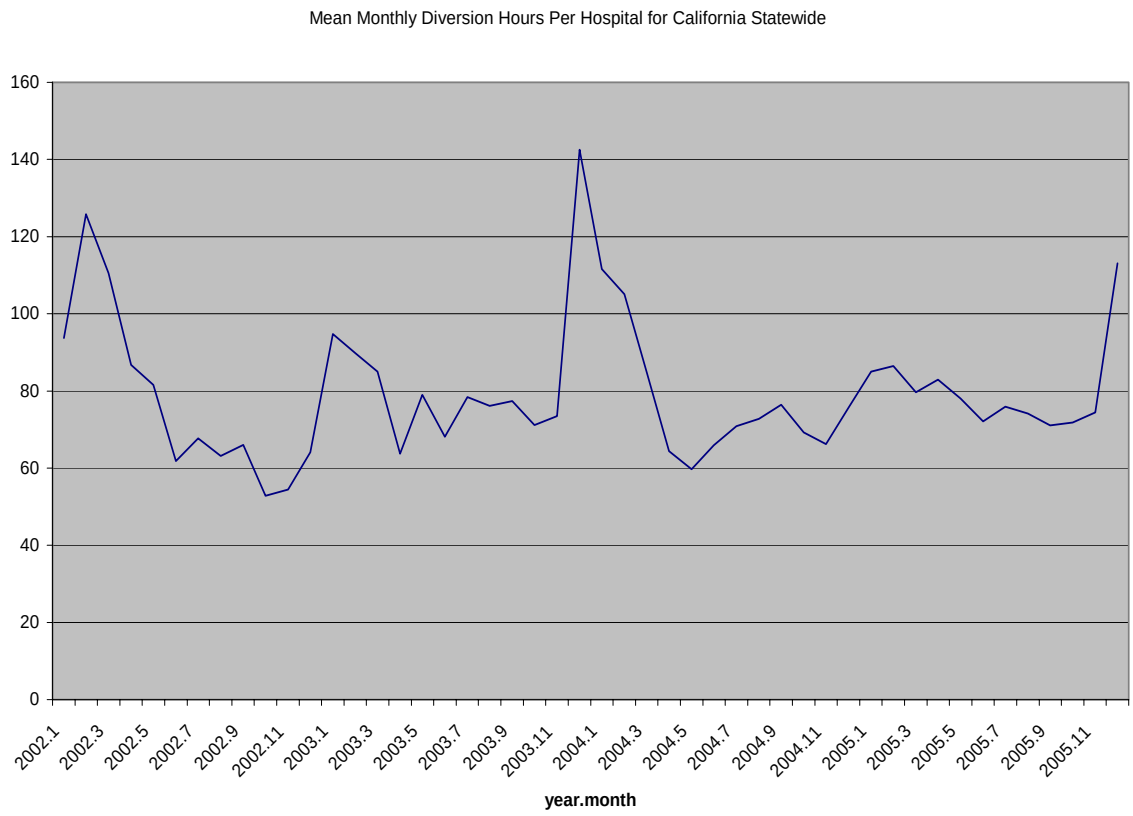

Figure 5. Mean Monthly Diversion Hours Per Hospital for State of California (2002-2005)

Even though diversion hours remain constant over this period, there are increasing proportions of hospitals diverting patients away. The proportion of hospitals on diversion status at any point during the year was approximately 63 percent or two thirds in 2002. This value has increased to approximately 74 percent or 3-quarters over the next three years. While total diversion hours decrease, the number of hospitals also decreases. Average hours of diversion have increased from 932 hours in 2002 to 978 hours in 2005.

To determine the statewide diversion impact for 2005, the average diversion hours, 978, is divided by 8,760, the total number of hours in a year. We obtain a result of 11 percent, meaning Statewide, hospital EDs were closed to ambulances 11 percent of the time in 2005. This result is consistent with Abaris Group's report to the California

Healthcare Foundation where they also find statewide diversion impact in 2005 to be 11 percent.[65] Table 3 below summarizes the diversion hours and hospital statistics for the State of California.

Year	No. of Hospitals	% Hospitals on ever on divert during the year	Total Hrs of Diversion	Average Hours of Diversion (hospitals with at least 1 hour of diversion)	Average Hours of Diversion (all hospitals)
2002	282	63	262,732	1476	932
2003	268	74	270,144	1371	1008
2004	273	73	251,830	1265	922
2005	263	75	257,311	1306	978

Table 3. Summary of Diversion Hours and Hospital Statistics (2002-2005)

B. DESCRIPTIVE ANALYSIS OF HOSPITAL CHARACTERISTICS

Table 4 below presents summary statistics for variables used in the manpower analysis. The main categories are hospital staffing, physical capacity, financial characteristics and demand for ED care (patient volume).

Of the 997 observations, 71 percent of hospitals were on "divert" status for at least an hour during a given year. These hospitals averaged 1,349 hours of annual diversion time. Oddly, hospitals which experience diversion generally have more registered nurses, licensed practitioner nurses and resident / intern doctors than hospitals which do not experience diversion. However this oddity may be explained by the smaller capacity and larger volume of ED patients seen by hospitals with diversion. On average, a typical hospital which experiences diversion has seven fewer ED patient treatment stations and sees 7,716 more ED patients than a hospital which does not experience diversion. While patient revenues for both types of hospitals are very similar, hospitals

[65] The Abaris Group. California Emergency Department Diversion Project (Report One). A Report to the California Healthcare Foundation. March 19, 2007.

with diversion generally provide more uncompensated care to patients, averaging $5 million more per annum than hospitals that do not experience diversion.

	All Hospitals		Hospitals without Diversion		Hospitals with Diversion		
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Dependent Variable							
Total Annual diversion Hours	891	1,381	0	0	1,451	1,514	*
Independent Variables							
Hospital Staffing Characteristics							
Registered Nurses	297	258	231	217	339	273	*
Licensed Practitioner Nurses	32	25	26	24	36	25	*
Student and Intern Doctors	24	87	9	34	33	107	*
Nurse-to-bed Ratio	1.57	0.68	1.60	0.65	1.55	0.70	
Student Physician-to-bed Ratio	0.06	0.19	0.03	0.08	0.09	0.23	*
Hospital Physical Capacity							
Staffed Bed Occupancy Rate	0.72	0.19	0.72	0.20	0.73	0.18	
Number of Beds in ED	22	17	25	20	20	16	*
Hospital-Control Characteristics							
Government-controlled	0.15	0.35	0.21	0.41	0.10	0.30	*
Investor-controlled	0.23	0.42	0.15	0.35	0.28	0.45	*
Hospital Type							
Teaching	0.09	0.29	0.02	0.15	0.13	0.34	*
Rural	0.10	0.30	0.24	0.43	0.02	0.13	*
Hospital Financial Characteristics							
Log (Net Patient Revenue)	16.71	5.46	16.94	4.64	16.57	5.92	
% Net Patient Rev (Medicare)	0.34	0.18	0.34	0.16	0.34	0.19	
% Net Patient Rev (Medicaid)	0.17	0.20	0.15	0.15	0.19	0.22	*
% Net Patient Rev (3rd Party)	0.34	0.21	0.39	0.19	0.32	0.22	*
% Net Patient Rev (Other)	0.15	na	0.12	na	0.16	na	
Uncompensated care (millions) [1]	15.31	19.94	12.25	18.57	17.24	20.54	
Demand for ED Care							
ED Visits[2]	31,701	21,096	26,222	18,046	33,938	21,841	
Proportion of Urgent Visits[3]	0.88	0.13	0.87	0.14	0.88	0.12	
Observations	997		385		612		

* Significant at 5% level (2-sample t-test for difference of means between hospitals with and without diversion)

[1] Uncompensated care comprises bad debts and charity cases

[2] ED visits were categorized as nonurgent, urgent, moderate, severe and critical.

[3] Proportion of urgent visits includes all ED visit categories except nonurgent.

Table 4. Manpower Analysis Summary Statistics (2002-2004)

C. DESCRIPTIVE ANALYSIS OF POPULATION ACCESS TO EMERGENCY DEPARTMENTS

In this section, we provide descriptive analyses for two forms of ED access. Subsection 1 presents the findings for distance to closest ED while subsection 2 presents the findings for diversion hours of the closest ED.

1. Distance to Nearest ED

For each zip code, changes in distance to the nearest ED are tracked over 15 years and the overall change is calculated. Table 5 displays changes in distance to nearest ED for 20,463 zip-year observations from 1990 to 2004. For clarity, zip codes which lack observations for any of the 15 years are dropped from the sample. Similar to Table 6, we also weight the sample according to matched zip code population to obtain a better estimate of the total population affected by the change in distance to the nearest ED.

The majority of the zip codes (66 percent of total population in California) experience no change in distance to nearest ED. 24 percent of Californians face an increase in distance to their nearest ED while 10 percent experience a decrease.

Distance to Nearest Hospital	Count of Zip Codes	% of all Zip Codes	Affected Population Size[2]	% of Total Population
Decrease	2,328	11.38	2,062	10.08
Increase	4,576	22.36	4,980	24.34
No change	13,559	66.26	13,421	65.59
Full Sample[1]	20,463	100.00	20,463	100.00

[1] Contains California Zip-Year observations for 15 years

[2] Weighted by population of each zip code

Table 5. Changes in Distance to Nearest ED (1990-2004)

2. Diversion Hours

Even though 66 percent of Californians experience no change in distance to the closest ED, increased diversion hours in those EDs would affectively shut down ED access temporarily. Table 6 displays aggregated diversion hours for 918 zip codes from 2002 to 2005. We classify a downward change in diversion hours of more than 10 hours as a "decrease" and upward changes of more than 10 hours as an "increase". Changes in diversion hours of magnitude ranging between -10 and +10 are categorized as "no change". Rather than providing only counts of zip codes, we also weight the sample according to matched zip code population to obtain a better estimate of the total population affected by the change in diversion hours.

We find that more zip codes experience an increase in diversion hours (39 percent of total population in California) than zip codes that experience no change (32 percent) and zip codes which experience a decrease (29 percent).

Diversion Hours	Count of Zip Codes	% of all Zip Codes	Affected Population Size[2]	% of Total Population
Decrease	248	27.02	267	29.08
Increase	341	37.15	355	38.67
No change	329	35.84	296	32.24
Full Sample[1]	918	100.00	918	100.00

[1] Contains California Zip-Year observations for 15 years

[2] Weighted by population of each zip code

Table 6. Changes in Diversion Hours of EDs (2002-2005)

D. DESCRIPTIVE ANALYSIS OF POPULATION HEALTH OUTCOMES

Table 7 presents the summary statistics for zip code population and demographic variables at the zip code level. The display format is as follows: a set of statistics for the full sample, the sample population which experiences no change, a decrease in distance and an increase in distance to the nearest ED. We describe four main demographic characteristics of each zip code: gender distribution, age distribution, race distribution and general income level. Results of 2-sample t-tests (alpha=0.05) are reported for the following distance categories: decrease against no change and increase against no change. The 2-sample t-test tests for differences between the means of the independent variables for the "no change" distance categories against distance categories which experience a change.

The data indicates that residents who experience an increase in distance to the nearest hospital ED tend to be zip codes of smaller population size. Conversely, residents who experience a decrease in distance to the nearest ED tend to be from zip codes of larger population size. Between "no change" and "increase distance" categories, we find no significant difference in zip code gender distribution that 50 percent of subpopulations are male. Mean proportion of population above the age of 65 averages between 12 to 14 percent, proportion of blacks centers around 5 percent and income per capita across the subpopulations averages $20,000-$23,000.

			Distance to Closest Hospital					
	Full Sample		No Change		Decrease		Increase	
Health Outcome	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Miles to closest hospital (driving)	6.38	7.69	6.20	7.44	8.35*	9.49	5.89*	7.20
Zip code population	23,034	19,918	22,815	20,250	20,171*	18,554	25,142*	19,375
Demographics								
Male	0.502	0.0427	0.501	0.0455	0.505*	0.0452	0.502	0.0312
Age>65	0.135	0.0799	0.140	0.0869	0.133*	0.0693	0.120*	0.0584
Black	0.051	0.0989	0.050	0.1016	0.049	0.1131	0.055*	0.0814
Income per capita	21,317	12,769	21,266	12,627	22,747*	14,014	20,740*	12,469
Zip-year observations[1]	20,463		13,559		2,328		4,576	

Source: U.S. Census Bureau

[1] 1567 missing observations omitted from sample

* Significant at 5% level (2-sample t-test against "No Change" distance category)

Table 7. Summary Demographic Statistics for Mortality Data (1990-2004)

Table 8 below presents the summary statistics of zip code level death counts by cause in California from 1990 to 2004. It reports figures in four columns: (1) the overall sample, (2) those living in zip codes which do not experience any change in distance to the closest hospital, (3) those living in zip codes which experience a decrease in distance to the nearest hospital, and (4) those living in zip codes which experience an increase in distance to the nearest hospital. Results of 2-sample t-tests (alpha=0.05) are reported for the following distance categories: decrease against no change and increase against no change. The 2-sample t-test tests for differences between the means of the independent variables for the “no change” distance categories against distance categories which experience a change.

We find fewer homicide deaths in zip codes experiencing an decrease in distance. For all causes of death, we consistently find that zip codes which experience no change in the distance to the nearest hospital have higher death rates than those zip codes which experience a change. However, we hesitate to conclude that this may be indicative of any trend because the total population size of zip codes which do not experience a change is

much larger than the other distance categories and therefore more likely to contain many more observations of the listed death categories. We provide more detailed trend analysis of the mortality rates in Chapter V.

			Distance to Closest Hospital					
	Full Sample		No Change		Decrease		Increase	
Health Outcome	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Total deaths per zip-year	158.67	138.60	157.71	141.05	140.57*	131.76	170.73*	133.46
Heart-related death rate	0.340%	0.0186	0.387%	0.0225	0.232%*	0.0016	0.254%*	0.0065
Unintentional injury / Suicide death rate	0.079%	0.0058	0.091%	0.0070	0.055%*	0.0007	0.056%*	0.0016
Cancer death rate	0.281%	0.0179	0.328%	0.0219	0.193%*	0.0014	0.188%*	0.0036
Chronic liver disease death rate	0.0205%	0.0029	0.0241%	0.0035	0.0134%*	0.0003	0.0132%*	0.0007
Homicide rate	0.0109%	0.0017	0.0117%	0.0020	0.0072%*	0.0002	0.0105%	0.0009
Zip-year observations	20,463		13,559		2,328		4,756	

Source: California Department of Health Services, Death Statistical Master Files

* Significant at 5% level (2-sample t-test against "No Change" distance category)

Table 8. Summary Statistics of Health Outcomes for Mortality Data (1990-2004)

V. MULTIVARIATE ANALYSIS AND RESULTS

This chapter presents results from the multivariate analyses. Section A discusses results pertaining to the effect of ED staffing and capacity on ED access while section B discusses results analyzing the effect of ED access on patient health outcomes.

A. HOSPITAL LEVEL ANALYSIS OF ED STAFFING AND CAPACITY

We analyze ED access using hospital level data available for the State of California from 2002 to 2005 in two parts. The first part is a probit model which allows us to examine which factors influence an ED's probability of being on divert at all during any given year. The dependent variable is a binary variable indicating whether or not a hospital has ever been on diversion during a specific year. The second part of the model restricts the data to hospitals which experience at least one hour of diversion in a given year and utilizes a fixed effects OLS regression technique to estimate the extent to which hospital characteristics affect the total hours of ED diversion. We choose this method because there is a substantial portion of hospitals which report zero diversion hours in any given year. This two-part method is a suitable and straightforward approach when dealing with a mass of observations clustered at a specific value (in our case, zero).[66]

As shown in Table 9, increasing the number of nurses can help reduce the probability of ED diversion. The probit model indicates that at a 5 percent significance level, a unit increase in nurse-to-bed ratio reduces the probability of ED diversion by approximately 7 percentage points. This confirms McCaig *et al's* survey findings that staffing shortages are partly responsible for ambulance diversion.[67]

Interestingly, we find the relationship between student physicians and ED diversion to be positively related. In other words, the probit model tells us that a unit

[66] The World Bank. "Technical Note: #11: Multivariate Analysis of Health Data: Non-linear Estimators." *Quantitative Techniques for Health Equity Analysis*: pp.1-13.

[67] Catharine W. Burt, Linda F. McCaig, "Staffing, Capacity and Ambulance Diversion in Emergency Departments: United States, 2003-2004." *Advance Data from Vital and Health Statistics; No.376.* Hyattsville, MD: National Center for Health Statistics; 2006: p. 6.

increase in resident / intern-to-bed ratio increases the probability of ED diversion by roughly 0.66, significant at 1 percent level. This result might seem counterintuitive at first. However, student physicians are interning in hospitals and require careful coaching and guidance by experienced medical staff. It is reasonable to consider that commitment of experienced medical staff to a teaching function potentially increases the amount of time needed to treat each case, thereby increasing the chances of a staffing shortage leading to ED diversion. This finding is consistent with the positive sign of the "teaching hospital" variable.

The number of beds in an ED represents its physical capacity to house patients seeking medical care. Of the 997 hospitals involved in this study, the average number of ED beds is 22. The results in Table 9 suggest that increasing the number of ED beds by 10 reduces the probability of ED diversion by almost 4 percentage points.

Government-controlled hospitals are less likely to experience diversion while investor-controlled hospitals increase the probability of ED closure. Compared to nonprofit hospitals, a government-controlled hospital has a lower probability of ED diversion by 27 percentage points while an investor-controlled hospital has a higher probability of ED diversion by approximately 19 percentage points. It should be noted that even though investor-owned hospitals are smaller in general, we obtain this result after controlling for ED capacity. It would be interesting for further research to be conducted on hospital-control types to determine if and how varying financial motivations (profit and nonprofit) can result in such different diversion outcomes.

Teaching hospitals are more likely to experience ED diversion. Compared to non-teaching hospitals, teaching hospitals are approximately 28 percentage points more likely to experience an ED closure. As before, we reason that a teaching hospital which commits clinical resources to a teaching function over and above the provision of medical care afforded by non-teaching hospitals is more likely to experience a staffing / resource shortage leading to temporary ED closure.

The probability of being on divert is 48 percentage points lower in rural hospitals compared to their urban counterparts. The geographical location of hospitals could in part

be capturing localized demand for emergency medical services since rural hospitals attend to slightly more than half the number of ED patient visits[68] urban hospitals see annually. All else equal, rural hospitals are potentially less likely to experience ED staffing (clinicians) and hospital capacity (beds) shortages which might plague their urban counterparts.

Source of revenue also seems to have some effect on whether a hospital is on divert. In particular, having more share of revenue from private payers (third party) reduces the probability of being on diversion status.

[68] Rural hospitals average 18,740 ED patients annually compared to urban hospitals which see more than 33,000 ED patients annually.

Marginal Effect of Hospital Characteristic on ED Diversion Status		
Independent Variable	(Y=divert)	
Nurse-to-Bed Ratio	-0.0656	(0.0306)**
Student Physician-to-Bed Ratio	0.6608	(0.2138)***
Staffed Bed Occupancy Rate	0.0322	(0.1111)
Number of Beds in ED	-0.0037	(0.0011)***
Government-Controlled	-0.269	(0.0628)***
Investor-Controlled	0.1898	(0.0384)***
Teaching Hospital	0.2795	(0.0531)***
Rural	-0.4837	(0.0590)***
log (Net Patient Revenue)	0.016	(0.0184)
% Net Patient Rev (Medicare)	-0.24	(0.3566)
% Net Patient Rev (Medicaid)	-0.4264	(0.3592)
% Net Patient Rev (3rd party)	-0.7761	(0.3723)**
log (ED visits)	0.0131	(0.0143)
Proportion of Urgent Visits	0.1141	(0.142)
y2003	0.1341	(0.0451)***
y2004	0.178	(0.0451)***
y2005	-0.3173	(0.0496)***
Constant		
Observations	973	

Standard errors in parentheses
* significant at 10%;
** significant at 5%;
*** significant at 1%

Table 9. Probit Model of Diversion Status: Change in Probability of ED Diversion Status due to a Unit Change in Hospital Characteristic

The second part of the manpower analysis model is restricted to hospitals which have experienced at least an hour of diversion in any given year. The dependent variable is log transformed diversion hours for a given year for each hospital. Table 10 reports the estimates for OLS and fixed effects OLS regression techniques. While fixed effects OLS generally produces regression estimates which are insignificant, OLS results largely confirm the findings from the first part of the manpower analysis model, that ED staffing, hospital capacity and patient demand characteristics all affect a hospital ED's diversion outcome.

From Table 10, effects of ED staffing characteristics are found to be similar to the probit model. Increasing the nurse-to-bed ratio by one reduces ED diversion duration by approximately 28 percent while the same increase for student physician-to-bed ratio increases an ED's diversion duration by almost 79 percent.

For number of ED beds and occupancy rate of staffed beds, the OLS model results in positive coefficients for both characteristics. It is interesting to note that more ED beds are associated with higher percent of diversion hours given that a hospital has non-zero diversion hour in a given year. However, the results indicate that a one percent increase in staffed bed occupancy rate increases ED diversion by roughly one and a half percent. This is consistent with the probit model's finding that hospital capacity is positively related to ED diversion hours.

Controlling for size and all other relevant factors, rural hospital EDs generally experience 72 percent[69] less diversion hours than urban hospital EDs. This is consistent with the finding that a one percent increase in ED patient visits increases diversion hours by 0.08 percent because rural hospitals typically encounter lower patient volumes than urban hospitals.

Unlike the probit model, however, we do not find hospital-control types to be significantly associated with ED diversion hours.

[69] If b is the estimated coefficient on a dummy variable and V(b) is the estimated variance of b then g = 100 (exp(b - V(b)/2) - 1) gives the estimated percentage impact on the dependent variable.

Independent Variable	(1) Ordinary Least Squares Y=log (diversion hours)		(2) Fixed Effects Y=log (diversion hours)	
Nurse-to-Bed Ratio	-0.2809	(0.1100)**	-0.0588	(0.0943)
Student Physician-to-Bed Ratio	0.7933	(0.3619)**	0.8472	(0.5629)
Staffed Bed Occupancy Rate	1.5476	(0.4060)***	-0.0240	(0.3151)
Number of Beds in ED	0.0091	(0.0042)**	-0.0043	(0.0068)
Government-Controlled	-0.3407	(0.2717)		na
Investor-Controlled	-0.1900	(0.1500)		na
Teaching Hospital	-0.1658	(0.2530)		na
Rural	-1.1584	(0.4736)**		na
log (Net Patient Revenue)	0.0726	(0.0631)	-0.1108	(0.1623)
% Net Patient Rev (Medicare)	-0.5378	(1.2256)	1.4994	(0.7728)*
% Net Patient Rev (Medicaid)	-0.3377	(1.1975)	0.4156	(0.9936)
% Net Patient Rev (3rd party)	-2.2730	(1.2677)*	0.9740	(0.7718)
log (ED visits)	0.0833	(0.0456)*	0.0244	(0.0230)
Proportion of Urgent Visits	0.4598	(0.5295)	-0.3206	(0.5086)
Constant	4.2044	(0.6738)***	7.6173	(2.8153)***
Observations	604		604	
R-squared	0.14		0.05	

Standard errors in parentheses
* significant at 10%;
** significant at 5%;
*** significant at 1%

Table 10. Fixed effects OLS Model of Diversion Hours: Percent Change in Diversion Hours due to a Unit Change of Hospital Characteristic

B. ZIP CODE LEVEL ANALYSIS OF ED ACCESS AND MORTALITY

In this section, we present three sets of results: trend analysis and two types of ED access analysis, one using distance (better regarded as a permanent change in ED access) and another using both distance and diversion hours (where we regard diversion hours as a temporary change in ED access). We study the zip code level mortality rates for the following causes of death: heart-related deaths, deaths from unintentional injuries and suicides, cancer deaths and deaths as a result of chronic liver disease and cirrhosis. Mortality rates are derived by dividing zip code level death counts (obtained from Office of Health Information and Research) by zip code population (obtained from the Census Bureau).

Subsection 1 presents the results for trend analysis where we further separate mortality rates into three distance categories: (1) population experiencing no change in distance to nearest hospital ED, (2) population experiencing decreased distance to nearest ED and (3) population experiencing increased distance to nearest ED. Subsection 2 analyzes the mortality rates by distance while subsection 3 analyzes mortality rates by distance and level of diversion hours.

1. Trend Analysis of Mortality Rates by Distance Categories: 1990-2004

Figure 6 presents heart-related death rates for the State of California from 1990-2004. The graph shows a distinct layering of heart-related death rates across the three distance categories. The population which experiences no change in distance to the nearest hospital ED has a mean mortality rate of 0.2812 percent (95% CI 0.2649% to 0.2975%), consistently reporting the highest heart-related death rates compared to a mean of 0.2083% for populations which experience a decrease in distance (95% CI 0.2034% to 0.2132%) and a mean of 0.22% (95% CI 0.2147% to 0.2527%) for those which experience an increase. While death rates for both “decrease distance” and increase distance” categories have remained relatively flat over the years, we observe a steep decline in death rates for the “no change” category between 1999 and 2000.

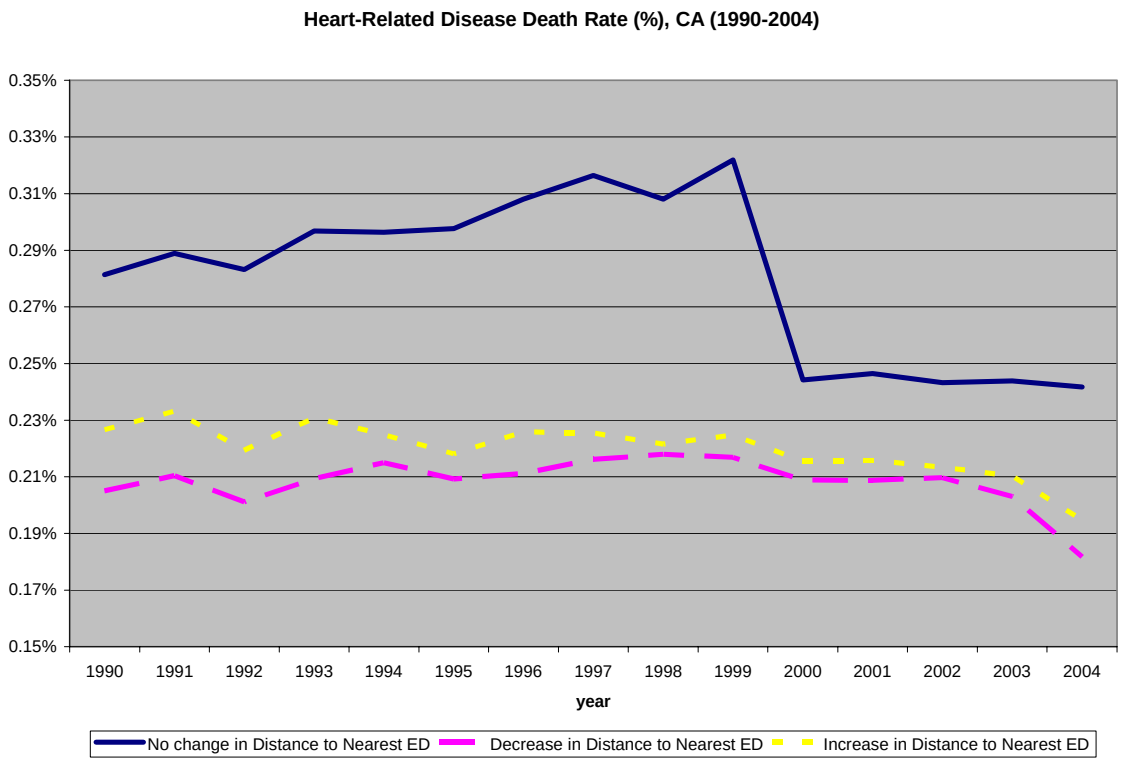

Figure 6. Heart-Related Disease Death Rate (%), California (1990-2004)

Figure 7 presents unintentional injury and suicide death rates for the State of California between 1990 and 2004. Again, we find a distinct layering of mortality rates between death rates of "no change" categories and categories which experience a change in distance. Zip code populations which experience no change in distance to the nearest ED generally have the highest mortality rates while zip codes which experience a change have the lowest. Populations which experience no change in distance to the nearest hospital ED have a mean suicide and unintentional injury death rate of 0.0563% (95% CI 0.05414% to 0.05846%) compared to a mean of 0.0448% (95% CI 0.04286% to 0.04674%) for populations which experience a decrease and a mean of 0.0436% (95% CI 0.04216% to 0.04504%) for populations which experience an increase.

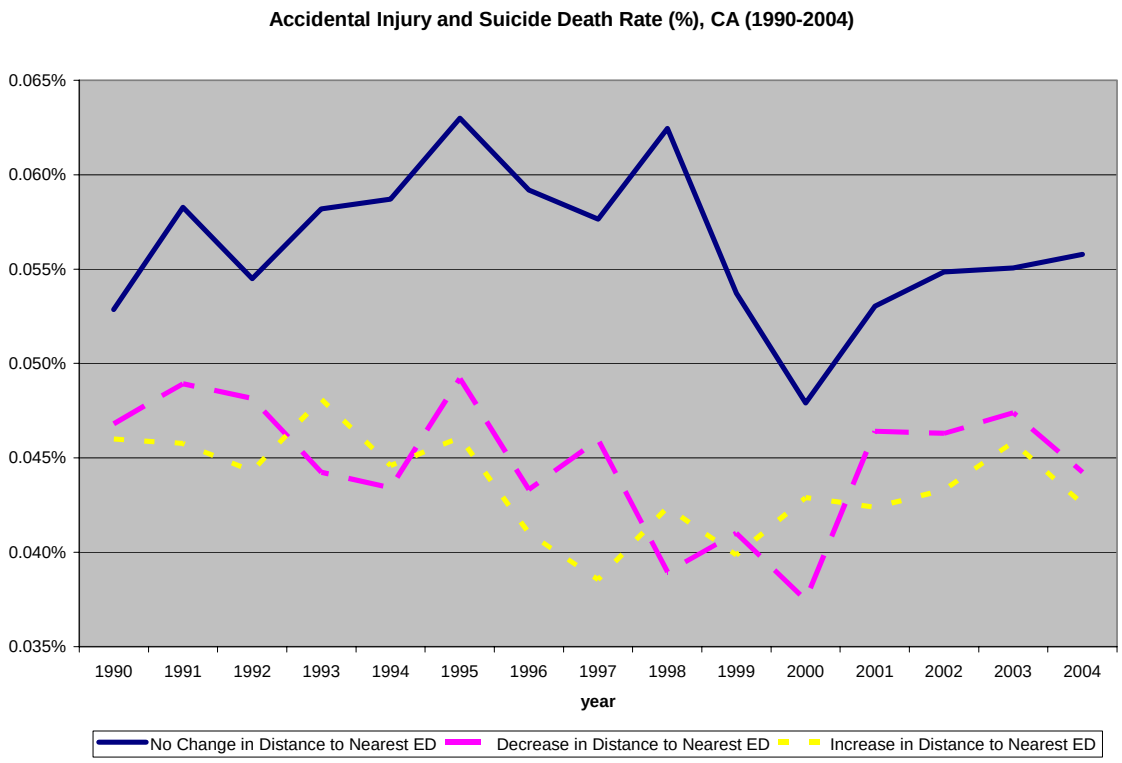

Figure 7. Unintentional Injury and Suicide Death Rate (%), California (1990-2004)

Unlike heart-related deaths and deaths resulting from unintentional injuries and suicides, cancer deaths are less time-sensitive in terms of access to immediate medical care. Figure 8 presents cancer death rates by distance categories for the State of California between 1990 and 2004.

From the trend lines in Figure 8, we observe a distinct stratification of cancer-related mortality rates by distance categories. "No change" categories tend to have higher death rates than categories which experience a change. Descriptive statistics suggest that populations which experience no change in distance to the nearest hospital ED (mean 0.2218%; 95% CI 0.2105% to 0.2331%) have higher cancer mortality rates than populations which experience a decrease, (mean 0.1724%, 95% CI 0.1674% to 0.1774%) and populations which experience an increase (mean 0.1653%, 95% CI 0.163% to 0.1676%).

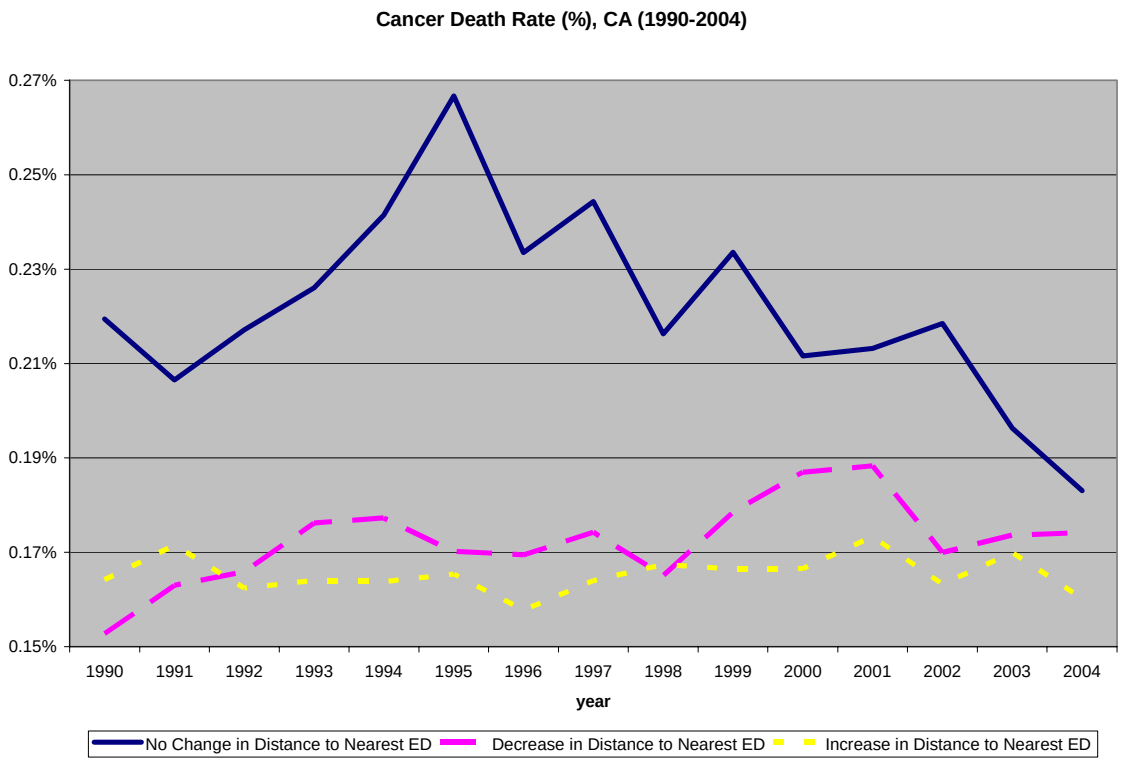

Figure 8. Cancer Death Rate (%), California (1990-2004)

Figure 9 presents chronic liver disease and cirrhosis death rates for the State of California from 1990 to 2004. Interestingly, while we expect chronic liver disease and cirrhosis death rates to be less sensitive to timely medical care than heart-related deaths and deaths from unintentional injuries and suicides, we do find some stratification of liver disease mortality rates across distance categories.

Populations which experience no change in distance to the nearest ED have the highest mean liver disease and cirrhosis death rate of 0.0146% (95% CI 0.01396% to 0.01524%) compared to a mean of 0.0107% (95% CI 0.009945% to 0.01146%) for populations which experience a decrease and a mean of 0.0119% (95% CI 0.01141% to 0.01239%) for populations which experience an increase.

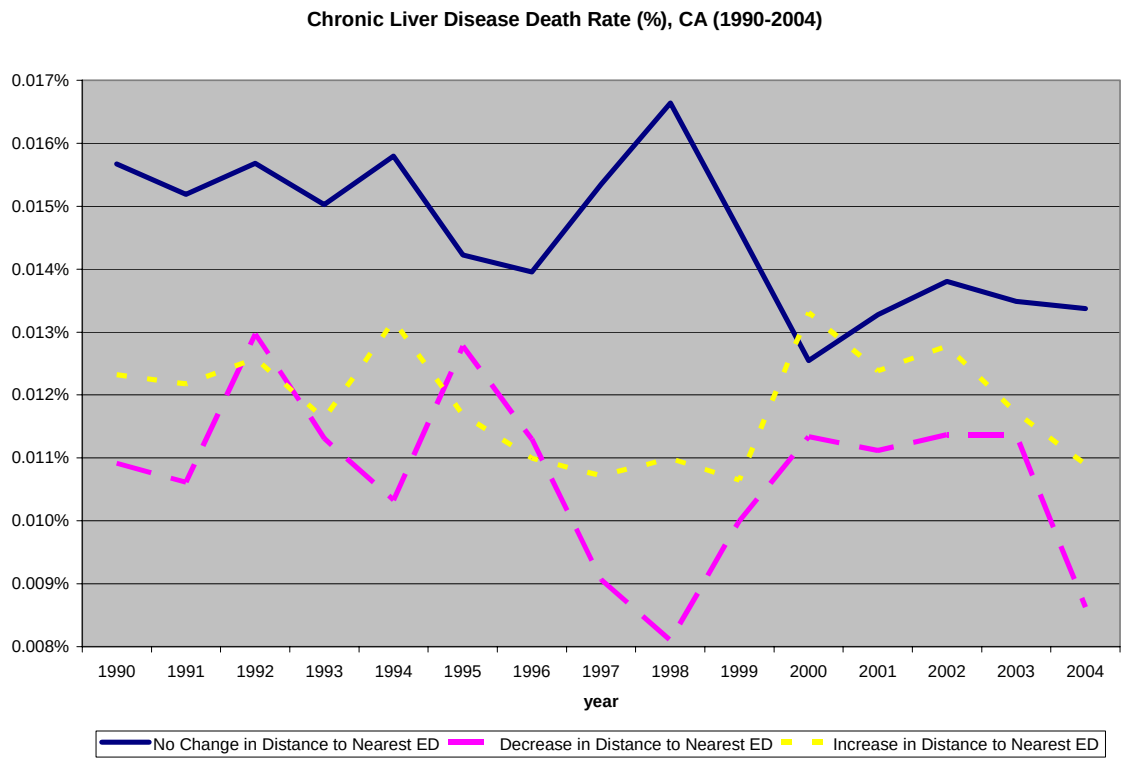

Figure 9. Chronic Liver Disease and Cirrhosis Death Rate (%), California (1990-2004)

2. Analysis of ED Distance and Mortality Rates

The ordinary least squares mortality regression results are reported in Table 11. These results consider the simple effect of changes in distance to the closest hospital on mortality rates by cause, identifying the effect of distance using both cross-sectional and cross-time variations but did not take into account serial correlation across years for the same zip code. Generally, distance to the closest ED is positively related or has no significant impact on mortality rates. Even if the impact on mortality rates is significant, the magnitude of the impact is extremely low.

Interestingly, while we expect distance to have an impact on heart-related mortality rates (a time-sensitive condition) we find distance to be an insignificant predictor of this mortality rate. Conversely, while we do not expect non-time-sensitive causes like chronic liver disease deaths to be affected by distance, results indicate that

such a positive relationship does exist. It appears that distance to the closest ED might capture the general level of medical care access in the area. Closer distances to EDs might be associated with quicker access to other medical care resources not captured by the model, therefore leading us to observe either insignificant or positive relationships between distance and mortality rates, regardless of the time-sensitivity of the condition.

We control for and report effects of demographic and financial characteristics on mortality rates. While total zip code deaths increase mortality rates, the magnitude of this increase in extremely low for all death categories.

Higher homicide rates also increase mortality rates. The magnitudes imply that a 1 percent increase in homicide rate results in a corresponding 2 percent increase in heart-related death rates. For all death categories, males consistently report lower mortality rates than women. For example, males are 7 percent less likely than women to be susceptible to heart-related deaths.

The elderly (individuals more than 65 years old) are a more vulnerable population. Our findings corroborate this as we find that compared to the younger population, the aged are approximately 4 percent more likely to die from heart-related diseases and cancer.

While gender does not seem to play a part in the reported causes of death, affluence does seem to lower mortality rates. A 10 percent increase in per capita income is associated with an approximately 3 percent decrease in both heart-related and cancer-related deaths.

Fixed effects mortality regression results are reported in Table 12. Using the fixed effects technique, observations which do not experience a change in distance to the closest ED drop out from the regression. As a result, distance to closest ED is an insignificant variable for all causes of death.

Independent Variable	(1) (Y=heart-related death rate)	(2) (Y=injury and suicide death rate)	(3) (Y=liver disease death rate)	(4) (Y=cancer-related death rate)
distance to closest ED	0.0000295	0.0000293	0.000009	-0.0000054
	(0.0000189)	(0.00000603)***	(0.00000307)***	(0.0000165)
total zip code deaths	-0.00000844	-0.0000036	-0.000000739	-0.00000983
	(0.00000105)***	(0.000000333)***	(0.00000017)***	(0.00000091)***
homicide rate	2.0517	0.1564	0.046	1.8291
	(0.0744)***	(0.0237)***	(0.0121)***	(0.0646)***
proportion male	-0.0722	-0.0314	-0.0073	-0.0661
	(0.0030)***	(0.0010)***	(0.0005)***	(0.0026)***
proportion elderly	0.0413	0.0048	-0.0004	0.0383
	(0.0017)***	(0.0005)***	(0.0003)	(0.0014)***
proportion black	-0.0003	-0.0002	-0.0001	-0.0001
	(0.0013)	(0.0004)	(0.0002)	(0.0012)
log (per capita income)	-0.0028	-0.001	-0.0001	-0.0025
	(0.0003)***	(0.0001)***	(0.0000)***	(0.0002)***
Constant	0.0616	0.0257	0.0054	0.0558
	(0.0033)***	(0.0010)***	(0.0005)***	(0.0028)***
Observations	20438	20438	20438	20437
R-squared	0.11	0.07	0.01	0.12

Standard errors in parentheses.

The key independent variable is the driving distance from each zip code population center to the closest hospital in a given year. Zip codes fewer than five deaths in any given year are excluded as are zip codes that do not have any deaths in all years.

* significant at 10%;

** significant at 5%;

*** significant at 1%

(14 year dummies were included in the analysis but excluded from the table)

Table 11. OLS Model of Mortality Rates (CA, 1990-2004): Change in Mortality Rate Due to a Unit Change in Independent Variable

Independent Variable	(1) (Y=heart-related death rate)	(2) (Y=injury and suicide death rate)	(3) (Y=liver disease death rate)	(4) (Y=cancer-related death rate)
distance to closest ED	-0.0000537	0.00000965	-0.0000042	0.0000178
	(0.0000407)	(0.0000153)	(0.00000886)	(0.0000328)
total zip code deaths	0.00000844	-0.00000348	0.000000931	0.0000126
	(0.00000105)***	(0.00000126)***	(0.000000733)	(0.00000271)***
homicide rate	0.532	-0.109	0.0277	0.1238
	(0.0516)***	(0.0194)***	(0.0112)**	(0.0418)***
proportion male	-0.0165	-0.0202	-0.0036	-0.0273
	(0.0051)***	(0.0019)***	(0.0011)***	(0.0041)***
proportion elderly	0.0702	0.012	0.0029	0.0355
	(0.0035)***	(0.0013)***	(0.0008)***	(0.0028)***
proportion black	-0.0186	-0.0029	-0.0007	-0.0083
	(0.0050)***	-0.0019	(0.0011)	(0.0040)**
log (per capita income)	-0.0005	-0.0004	-0.0001	-0.0007
	(0.0006)	(0.0002)	(0.0001)	(0.0005)
Constant	0.0041	0.0123	0.0026	0.0164
	(0.0065)	(0.0025)***	(0.0014)*	(0.0053)***
Observations (total)	20438	20438	20438	20437
Observations (utilized)	1565	1565	1565	1565
R-squared	0.03	0.01	0	0.01

Standard errors in parentheses.

The key independent variable is the driving distance from each zip code population center to the closest hospital in a given year. Zip codes fewer than five deaths in any given year are excluded as are zip codes that do not have any deaths in all years.

* significant at 10%;

** significant at 5%;

*** significant at 1%

(14 year dummies were included in the analysis but excluded from the table)

Table 12. Fixed Effects OLS Model of Mortality Rates (CA, 1990-2004): Change in Mortality Rate Due to a Unit Change in Independent Variable

3. Analysis of Effects of Diversion Hours and Distance on Mortality Rates

The ordinary least squares mortality regression results for 2002-2004 are reported in Table 13. Our data panel is limited to 2002-2004 because diversion data only starts from 2002 while latest mortality data is only available till 2004. In this final analysis, we analyze mortality rates using both measures of ED access. The key independent variables in this regression are diversion categories (levels of diversion hours) in each year and spherical distance from each zip code population center to the closest ED.

To capture the general level of diversion for each hospital, we obtain a three year average for each hospital. We determine diversion categories by dividing the sample into three equally-sized quantiles of diversion hours. Diversion levels are classified as low, medium and high. Low diversion levels average 4.5 hours of ED diversion per year. Medium and high diversion levels average 375 hours and 2378 hours per year respectively.

The results for the distance variable are consistent with Table 11 and 12: we find either a positive or insignificant relationship between distance and mortality rates. Increased distances to the closest ED increase mortality rates associated with heart-related, accidental injury and suicide-related and cancer-related deaths. Once again, however, the magnitude of this increase is extremely small: a 1 mile increase in distance leads to a 0.013 percent increase in heart-related deaths, 0.006 and 0.004 percent increase in mortality rates respectively for injury and suicide-related deaths.

For diversion levels, the difference between low and medium diversion levels is insignificant. It is interesting to note, however, that mortality rates for heart-related and cancer-related deaths are lower for the high diversion category than for the low diversion category. Though the magnitude of the difference may be small (less than one percent for both cases), it produces a counterintuitive result which implies that an increase in distance to the closest ED leads to lower mortality rates. Further study may be required to verify this result.

We corroborate previous findings that men experience lower mortality rates than women for the reported causes of death. Also, higher per capita income results in lower mortality rates. Similar to results from Table 11, a 10 percent increase in per capita income lowers heart-related deaths by approximately 3 percent.

For the analysis of diversion level and distance on mortality rates, we do not report the fixed effects model since diversion level (one of the two key independent variables) is time invariant.

Independent Variable	(1) (Y=heart-related death rate)	(2) (Y=injury and suicide death rate)	(3) (Y=liver disease death rate)	(4) (Y=cancer-related death rate)
diversion level (medium)	-0.001043	-0.000461	-0.000096	-0.00025
	(0.000797)	(0.000324)	(0.000135)	(0.000274)
diversion level (high)	-0.001459	-0.000717	-0.000136	-0.000405
	(0.000790)*	(0.000321)**	(0.000134)	(0.000272)
distance to closest ED	0.000127	0.000061	0.000015	0.000039
	(0.000053)**	(0.000022)***	(0.000009)	(0.000018)**
total zip code deaths	-0.000012	-0.000006	-0.000001	-0.000003
	(0.000003)***	(0.000001)***	(0.000000)***	(0.000001)***
homicide rate	-1.536745	-1.060296	-0.079142	-0.106027
	(1.429272)	(0.580709)*	(0.242378)	(0.492244)
proportion male	-0.179257	-0.072568	-0.017089	-0.036293
	(0.007594)***	(0.003085)***	(0.001288)***	(0.002615)***
proportion elderly	-0.011467	0.002675	-0.002021	-0.003192
	(0.004969)**	(0.02019)	(0.000843)**	(0.001711)*
proportion black	0.000567	0.000958	0.000011	-0.000237
	(0.003432)	(0.001394)	(0.000582)	(0.001182)
log (per capita income)	-0.002926	-0.001146	-0.00026	-0.000733
	(0.000711)***	(0.000289)***	(0.000121)**	(0.000245)***
Constant	0.125329	0.050571	0.011716	0.026999
	(0.008490)***	(0.003450)***	(0.001440)***	(0.002924)***
Observations	3216	3216	3216	3216
R-squared	0.15	0.16	0.05	0.06

Standard errors in parentheses.

The key independent variables are the driving distance from each zip code population center to the closest hospital in a given year and categorical variables capturing annual diversion hours for each hospital. Zip codes fewer than five deaths in any given year are excluded as are zip codes that do not have any deaths in all years. Diversion levels are classified as low (base case), medium and high. Low diversion levels average 4.5 diversion hours per year. Medium and high diversion levels average 375 hours and 2378 hours per year.

* significant at 10%;

** significant at 5%;

*** significant at 1%

2 year dummies have been included in the analysis but excluded from the table

Table 13. OLS Model of Mortality Rates (CA, 2002-2004): Change in Mortality Rate Due to a Unit Change in Independent Variable

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VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This section provides the conclusions and discussion on the findings from the study. Subsection 1 provides conclusions from the trend analysis of diversion hours in Californian EDs from 2002-2005. Subsection 2 discusses the conclusions from hospital level analyses of ED staffing and capacity. Subsection 3 discusses conclusions from zip code level analyses of ED staffing and capacity.

1. Trend Analysis of Diversion Hours in California EDs

Patient loading on Californian EDs is increasing. While the number of hospital EDs has decreased from 282 in Jan 2002 to 263 in Dec 2005, the mean diversion hours per hospital ED has increased from 77 hours in 2002 to 80 hours in 2005. Also, the proportion of EDs on diversion status has increased from 63 percent in 2002 to 74 percent in 2005.

AB 394 (the Californian legislation mandating nurse-to-patient ratios of 1:4 for acute general hospitals) appears to have registered a temporary impact on hospital diversion hours. We identify a temporary surge in mean diversion hours between Dec 2003 and Feb 2004 which corresponds well with the legislation of AB 394 in Jan 2004. However, we are unsure at this point if the steep decline in mean diversion hours following the surge is indicative of hospital EDs having coped with the new law or if it is due to typical cyclical trends.

The statewide impact of diversion is 11 percent for 2005. This means that in 2005, EDs in California were closed to residents 11 percent of the time. Our findings are consistent with the Abaris Group's report[70] to the California Healthcare Foundation where they also determine statewide ED diversion impact in 2005 to be 11 percent.

[70] The Abaris Group. California Emergency Department Diversion Project (Report One). A Report to the California Healthcare Foundation. March 19, 2007.

2. Hospital Level Analysis of ED Staffing and Capacity

Our two-part analysis reveals some interesting relationships between ED capacity and staffing characteristics and ED diversion hours. We highlight a few important results in this conclusion. Increasing the number of nurses can help reduce the probability of ED diversion. This finding is consistent with McCaig *et al's* survey findings that staffing shortage is one of the main reasons for ambulance diversion. Our probit model indicates that a unit increase in nurse-to-bed ratio reduces the probability of ED diversion by approximately 7 percentage points.

Increasing the number of intern / student doctors appears to have an adverse impact on ED diversion hours. A one unit increase in intern-to-patient ratio increases the probability of ED diversion by 0.66. It is reasonable to expect student physicians interning in hospitals to require careful coaching and guidance by experienced medical staff. The commitment of experienced medical staff to a teaching function potentially increases the amount of time needed to treat each case, thereby increasing the chances of a staffing shortage leading to ED diversion. The same can be said for teaching hospitals, which are 28 percentage points more likely than non-teaching hospitals to be on divert. We reason that a teaching hospital which commits clinical resources to a teaching function over and above the provision of medical care afforded by non-teaching hospitals is more likely to experience a resource shortage leading to temporary ED closure.

Increasing the number of beds in an ED reduces the probability of being on divert. We find that increasing the number of ED beds by 10 reduces the probability of ED diversion by almost 4 percentage points.

Compared to investor-controlled hospitals, government-controlled hospitals are less likely to experience diversion. Compared to nonprofit hospitals, a government-controlled hospital has a lower probability of ED diversion by 27 percentage points while an investor-controlled hospital has a higher probability of ED diversion by approximately 19 percentage points.

Rural hospitals are less likely than urban hospitals to be on divert. Empirically, rural hospitals are 48 percentage points less likely to be on divert compared to their urban

counterparts. The geographical location of hospitals could in part be capturing localized demand for emergency medical services since rural hospitals attend to approximately half the number of ED patient visits urban hospitals see annually.

3. Zip Code Level Analysis of ED Access and Mortality

For the last part of the analysis, we examine the effect of ED access on mortality rates, analyzing two types of ED access—changes in distance to the closest ED and changes in diversion hours of the closest ED.

We find that increased distance to the closest ED is associated with either no change or higher mortality rates. In particular, we find increased distance to be associated with higher mortality rates for heart-related, injury and suicide-related and cancer-related deaths. The magnitude of this increase, however, is small. For heart-related deaths, a 1-mile increase in distance leads to a 0.013 percent increase in mortality rates. Results indicate that mortality rates are not sensitive to both time- or non-time-sensitive causes of death. This may imply that distance to closest ED signals general accessibility to medical care. People living closer to EDs might have better access to other forms of medical care and have lower mortality rates for causes of death that are not time-sensitive. In addition, we find that affluence is associated with lower mortality rates. A one percent increase in per capita income lowers heart-related deaths by approximately 3 percent.

For diversion levels, we obtain a counterintuitive result which implies that increased distances led to lower mortality rate. Mortality rates for heart-related and cancer-related deaths are found to be lower for the high diversion category than those for the low diversion category. Further study is needed to verify this result.

B. RECOMMENDATIONS FOR FUTURE WORK

Due to data limitations, this study utilizes aggregated mortality counts at the zip code level (obtained from California Department of Health Services, Death Statistical Master Files). Using data at aggregated levels necessarily implies that the established linkages between ED access (as measured by distance to closest ED and diversion hours of the closest ED) are imprecise at best. Future research on this topic could consider using individual level mortality data to obtain more precise linkages between ED access and mortality.

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